Four Modalities of Single Implant Treatment in the Anterior Maxilla: A Clinical, Radiographic, and Aesthetic Evaluation

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ABSTRACT

Purpose: To document the outcome of single implants in the anterior maxilla following four routine treatment modalities when performed by experienced clinicians in daily practice using the same implant system and biomaterials.

Material and Methods: A retrospective study in patients who had been treated by two periodontists and two prosthodontists in 2006 and 2007 was conducted. The four treatment modalities practically covered every clinical situation and included standard implant treatment (SIT), immediate implant treatment (IIT), implant treatment in conjunction with guided bone regeneration (GBR), and implant treatment in grafted bone (BGR) harvested from the chin. All implants were installed via flap surgery. Patients were clinically and radiographically examined. Complications were registered and the aesthetic outcome (pink esthetic score [PES] and white esthetic score [WES]) was rated. A blinded clinician who had not been involved in the treatment performed all evaluations. Patient's aesthetic satisfaction was also registered.

Results: One hundred four out of 115 eligible patients (44 SIT, 28 IIT, 18 GBR, and 14 BGR) received at least one single NobelReplace tapered TiUnite® (Nobel Biocare, Göteborg, Sweden) implant in the anterior maxilla and were available for evaluation. Clinical parameters (implant survival: 93%, mean plaque level: 24%, mean bleeding on probing: 33%, and mean probing depth: 3.2 mm) and mean bone level (1.19 mm) did not differ significantly between treatment modalities. Postoperative complications were more common following GBR/BGR (>61%) when compared with SIT/IIT (<18%) ($p < .001$). BGR was in 4/14 patients associated with permanent sensory complications at the donor site. Technical complications occurred in 9/104 patients. SIT and IIT showed similar soft tissue aesthetics (PES: 10.07 and 10.88, respectively), however major alveolar process deficiency was common (>15%). PES was 9.65 for GBR. BGR showed inferior soft tissue aesthetics (PES: 9.00; $p = .045$) and shorter distal papillae were found following GBR/BGR ($p = .009$). Periodontal disease (odds ratio [OR]: 13.0, $p < .001$), GBR/BGR (OR: 4.3, $p = .004$), and a thin-scalloped gingival biotype (OR: 3.7, $p = .011$) increased the risk for incomplete distal papillae. WES was 7.98 for all patients considered. Poor agreement was found between objective and subjective aesthetic ratings.

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Conclusions: All treatment modalities were predictable from a clinical and radiographic point of view. However, advanced reconstructive surgery, especially BGR, increased the risk for complications and compromised aesthetics. Research is required on the prevention and minimally invasive treatment of buccal bone defects at the time of tooth loss to avoid complex therapy.

KEY WORDS: bone augmentation, dental implants, guided bone regeneration, immediate, pink esthetic score, single tooth

INTRODUCTION

Single implant treatment is considered a predictable and straightforward concept, at least when sufficient bone volume is present allowing for implant surgery according to standard principles. In the hands of experienced clinicians and following careful case selection, immediate implant installation in an extraction socket may be a viable alternative for this standard approach as shown by at least four randomized controlled studies.[1–4] Reality shows, however, that some hard tissue augmentation is quite often necessary especially in the anterior maxilla. Indeed, postextraction bone remodeling resulting in major resorption seems inevitable.[5–7] Mainly for aesthetic reasons, the clinician may want to compensate for this loss by the application of autogenous bone and/or biomaterials. In a first scenario, implant placement and hard tissue augmentation are combined in the same surgical intervention. Cases with small to moderate hard tissue deficiency not compromising the primary implant stability may be treated accordingly and with success as previously described.[8–10] In a second scenario, hard tissue augmentation precedes implant surgery. Autogenous block grafts with or without the use of biomaterials are applied to restore advanced hard tissue deficiency. Several months following such reconstructive surgery, implants can be installed according to standard principles. Albeit successful results have also been described for these complex cases,[11,12] it is difficult to compare the outcome of aforementioned treatment concepts based on the available literature. Indeed, heterogeneity in terms of care providers, implant system, biomaterials, and follow-up may render any conclusion in this respect highly biased. In addition, aesthetic aspects of treatment outcome have been underexposed to research. Hence, the objective of the present study was to document the outcome of single implants in the anterior maxilla following abovementioned treatment modalities when performed by experienced clinicians in daily practice using the same implant system and biomaterials.

MATERIALS AND METHODS

Patient Selection

This study included data on patients who had been consecutively treated for single-tooth implants in 2006 and 2007. The patients were selected and invited for examination on the basis of the following inclusion criteria:

1. All surgical and restorative treatments performed by two experienced periodontists, respectively, prosthodontists at the Dental Clinic of the Free University in Brussels (VUB) or private practice;
2. Single implant treatment in the anterior maxilla[15–25] using one implant system (NobelReplace tapered TiUnite®, Nobel Biocare, Göteborg, Sweden);
3. One of the following routine treatment modalities performed: standard implant treatment (SIT), immediate implant treatment (IIT), implant treatment in conjunction with guided bone regeneration (GBR), and implant treatment in grafted bone (BGR) as described in detail below;
4. Natural teeth present both mesial and distal to the implant.

Exclusion criteria were as follows:

1. Vertical alveolar process deficiency;
2. Submerged healing except following GBR;
3. Connective tissue grafting;
4. Papilla preservation flaps;
5. Flapless surgery.

The study was conducted in accordance with the Helsinki declaration of 1975 as revised in 2000 and the protocol was approved by the ethical committee of the University Hospital in Brussels.

SIT

In this context, SIT refers to straightforward implant therapy in sites where the failing tooth had been removed at least 6 weeks earlier. The criteria used by the authors for SIT can be found in Table 1. Details on the

TABLE 1 Hard and Soft Tissue Criteria Used by the Authors in the Decision-Making Process

	SIT	IIT	GBR	BGR
Hard tissue criteria	Sufficient volume to ensure ≥1.5-mm bone at the buccal aspect of the implant	No apical pathology; buccal bone wall intact; ≥5-mm bone height apical to the socket	Minor horizontal buccal bone defect (<1.5-mm bone at the buccal aspect of the implant)	Advanced horizontal buccal bone defect (≤3-mm orofacial width of the ridge)
Soft tissue criteria	Thick or thin gingival biotype*	Ideal soft tissue level and contour; thick gingival biotype*	Thick or thin gingival biotype*	Thick or thin gingival biotype*

SIT = standard implant treatment; IIT = immediate implant treatment; GBR = guided bone regeneration; BGR = implant treatment in grafted bone.
*Gingival biotype based on the transparency of the periodontal probe while probing the buccal sulcus of a central upper incisor.[13]

surgical and restorative procedures have been described in a recent paper[14] and are illustrated in Figure 1. In brief, a standard mucoperiosteal flap was elevated following sulcular incision at both teeth facing the single-tooth gap and a palatally oriented crestal incision. Vertical releasing incisions were never made. Thereupon, all patients received one or more commercially available implants positioned as described by Buser and colleagues.[15] Sites were occasionally underprepared to ensure primary implant stability and nonsubmerged healing. The surgical procedure was terminated by placing a healing abutment and single sutures (Vicryl® 5/0, Johnson & Johnson, St-Stevens-Woluwe, Belgium). After 3 months, restorative treatment was initiated. Within weeks, permanent cemented restorations were installed. Two were full-ceramic crowns.

IIT

The criteria used by the authors for IIT can be found in Table 1. Details on the surgical and restorative procedures have been earlier described[16] and are illustrated in Figure 2. In brief, mucoperiosteal flaps were elevated fully reflecting the papillae, yet without vertical releasing incisions. Following tooth removal using periotomes, patients received one or more commercially available implants hereby mainly engaging the palatal wall. A correct three-dimensional positioning of the implant principally as described by Buser and colleagues[15] was considered of pivotal importance. Sites were deliberately underprepared to ensure primary implant stability of at least 35 Ncm. Following implant installation, an impression was made using an appropriate open-tray impression post and impression material (Elite® implant medium, Zhermack, Badia Polesine, Italy) for a screw-retained provisional acrylic crown that was installed within 3 hours out of occlusion and articulation. Each provisional crown was fabricated using an engaging titanium temporary abutment and hollowed denture tooth. The latter was individualized using autopolymerizing acrylic resin (Palavit® 55 VS, Heraeus Kulzer, Hanau,

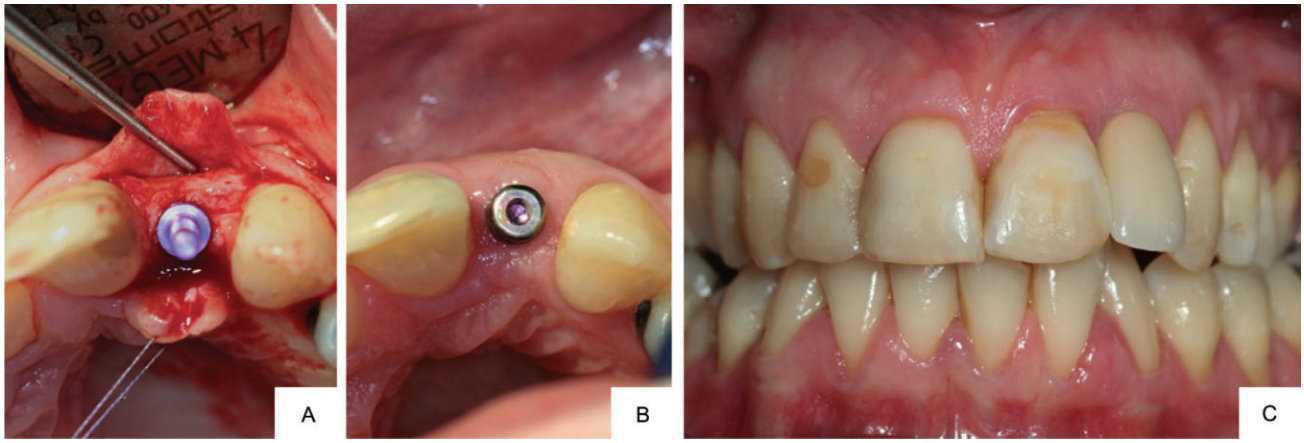

Figure 1 SIT. Standard mucoperiosteal flap elevation with direction indicator in situ (A). Situation after 3 months of osseointegration (B). Acceptable aesthetic outcome (C).

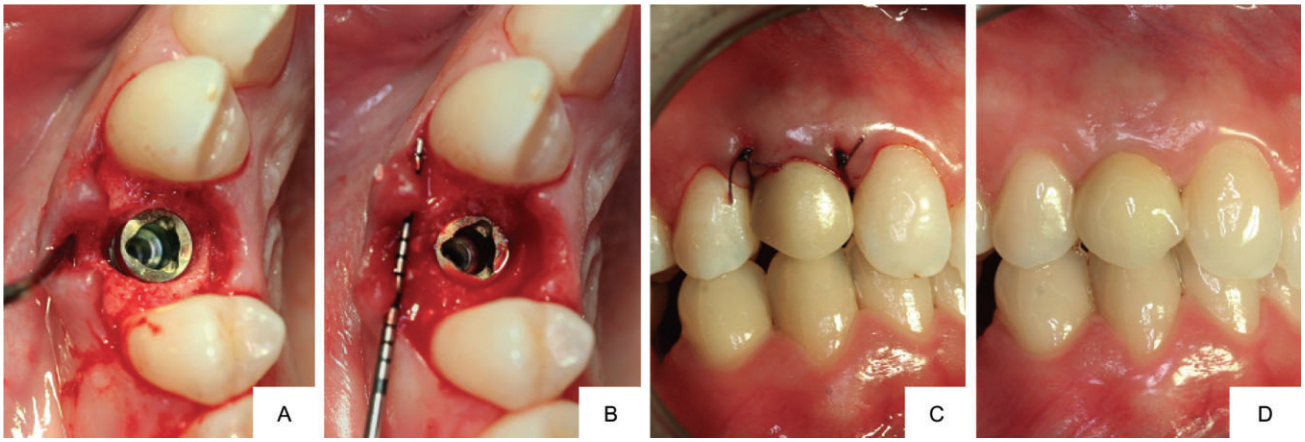

Figure 2 IIT. Implant installed in extraction socket (A). Bone gap filled with deproteinized bovine bone particles (B). Screw-retained provisional acrylic crown placed at the day of surgery (D). Perfect aesthetic outcome (D).

Germany). When present, the gap between the implant and socket wall was filled with deproteinized bovine bone particles (Bio-Oss® 0.25–1 mm, Geistlich Biomaterials, Wolhusen, Switzerland). Single sutures closed the wound. After 3 to 6 months, provisional crowns were replaced by permanent cemented restorations. Three were full-ceramic crowns.

Implant Treatment in Conjunction with GBR

In this context, implant treatment in conjunction with GBR refers to complex implant therapy in sites where the failing tooth had been removed at least 6 weeks earlier. The criteria used by the authors for GBR can be found in Table 1. Details on the surgical and restorative procedures have been described in detail[10] and are illustrated in Figure 3. In brief, a wide mucoperiosteal flap was elevated following sulcular incision at both teeth facing the single-tooth gap and a palatally oriented crestal incision. Two vertical releasing incisions were made at the buccal paramedian aspect. Thereupon, all patients received one or more commercially available implants positioned as described by Buser and

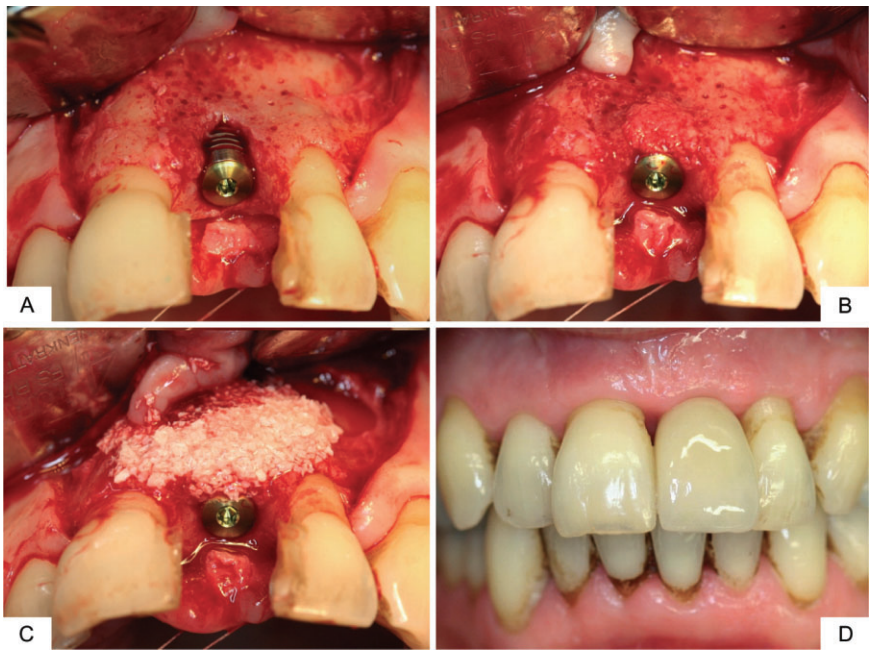

Figure 3 GBR. Wide mucoperiosteal flap, implant installed, buccal bone dehiscence present (A). Autogenous bone chips applied onto the implant (B). Bovine bone particles covering the buccal aspect of the ridge (C). Acceptable aesthetic outcome (D).

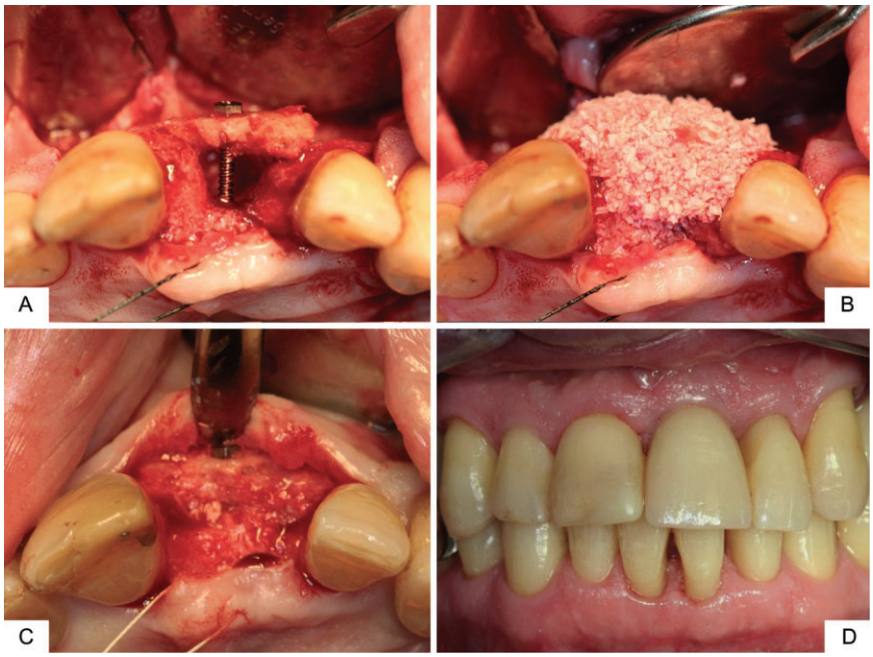

Figure 4 BGR. Wide mucoperiosteal flap, block graft secured with fixation screws (A). Mixture of bone chips and deproteinized bovine bone particles filling the gap between the recipient site and the block graft, bovine bone particles covering the buccal aspect of the ridge (B). Re-entry after 6 months to proceed with SIT (C). Acceptable aesthetic outcome (D).

colleagues.[15] Multiple bone perforations were performed in the buccal bone wall and the periosteum was released. In case of bone dehiscence, autogenous bone chips from the base of the alveolar process and/or nasal spine were applied. In all cases, deproteinized bovine bone particles covered the buccal aspect of the ridge. Two or more layers of a collagen membrane (Bio-Gide® 25 × 25 mm, Geistlich Biomaterials) stabilized the grafting material. The GBR technique made a two-stage procedure inevitable. Thus, tension-free primary wound closure was pursued in all patients by means of single sutures. After 3 months of osseointegration, implants were uncovered usually via a punch technique and healing abutments were placed. The restorative treatment was initiated a few weeks later. In all patients, permanent cemented restorations were installed. Only one was a full-ceramic crown.

BGR

Whenever the surgical site showed too limited bone volume for proper implant anchorage (≤3 mm orofacially), implant surgery was postponed and horizontal ridge augmentation was performed as illustrated in Figure 4. An autogenous block graft from the chin was used for this purpose basically as described by von Arx and Buser.[17] In brief, a horizontal incision was made at the donor site, more specifically at least 5 mm below the free gingival margin of the lower incisors. Following mucoperiosteal flap elevation, a block graft with appropriate dimensions was harvested from the symphysis and secured onto the recipient site with fixation screws. The flap design for BGR at the recipient site was identical to the outline described earlier for GBR. The gap between the block graft and the recipient site was filled with a mixture of bone chips and deproteinized bovine bone particles. A small amount of these particles was also applied on top of the block graft. Two or more layers of a collagen membrane stabilized the grafting material. Finally, tension-free primary wound closure was pursued in all patients by means of single sutures. Following 6 months, fixation screws were removed and SIT was performed as described earlier. In all patients, permanent cemented restorations were installed. Only one was a full-ceramic crown.

Apart from tooth extraction and uncoverage of implants following GBR, all surgical procedures included antibiotic and analgesic therapy (amoxicillin/clavulanic acid 500 mg and ibuprofen 600 mg), both started 1 hour preoperatively. Oral disinfection was performed using a 0.2% chlorhexidine digluconate mouthwash (Corsodyl®, GlaxoSmithKline, Genval, Belgium).

Clinical Evaluation

All patients were clinically reexamined in June 2009 by the same blinded clinician who had not been involved in the treatment. Besides implant survival, the following parameters were registered at the implant restoration as well as at the contralateral tooth:

1. Plaque score. A score (0 = no visible plaque; 1 = visible plaque) was given at four sites per tooth and implant (mesial, midfacial, distal, and palatal).
2. Probing depth was measured to the nearest 0.5 mm at four sites per tooth and implant (mesiofacial, facial, distopalatal, and palatal) using a manual probe (PCPUNC 15, Hu-Friedy®, Leimen, Germany).
3. Bleeding on probing. A score (0 = no bleeding; 1 = bleeding) was given at four sites per tooth and implant (mesial, midfacial, distal, and palatal).

Radiographic Evaluation

Standard intra-oral radiographs were made of all implants using the long-cone paralleling technique and a plastic x-ray holder (XCP Bite Block, Dentsply Rinn, Elgin, IL, USA). All radiographs were scanned (300 dpi) and digitized (SprintScan 35 Plus, Polaroid, Cambridge, MA, USA). Marginal bone levels (distance from the implant-abutment junction to the first visible bone-to-implant contact) were determined mesial and distal to the implant by the use of a computer program (Vixwin 2000 v1.11, Dentsply Gendex, Lake Zurich, Switzerland) and by the same blinded clinician.

Patient records were scrutinized for intra-oral radiographs that had been taken immediately after implant surgery. Such baseline radiographs were available on 38 implant cases following all treatment modalities and allowed for actual bone loss calculations.

Complications

Patient records were scrutinized for biologic and technical complications. For the former, a distinction was made between *postoperative complications* (major swelling, bleeding, hematoma, and pain), *infectious complications* (abscess, fistula, membrane exposure, and graft exposure), and *permanent complications* (hypoesthesia of the soft tissues and sensitivity loss of one or more teeth). *Technical complications* that were specifically looked for included loosening of the abutment screw, loss of retention of the crown, and fracture of components. As files were possibly incomplete, patients were also asked if any of the aforementioned complications occurred in the follow-up period and if they would undergo the same treatment again given their experience. An investigator who had not been involved in the treatment asked these questions.

Aesthetic Evaluation

The pink esthetic score (PES) by Fürhauser and colleagues[18] and the white esthetic score (WES) by Belser and colleagues[19] were used to evaluate the aesthetic outcome of the peri-implant soft tissues and the implant crown, respectively. Both were recorded by the same blinded clinician who had not been involved in the treatment.

Patient's Aesthetic Satisfaction

Patients were asked to give their opinion on the aesthetic treatment outcome based on the two following questions: "how satisfied are you with the aesthetic outcome of the gums surrounding the crown?" and "how satisfied are you with the aesthetic outcome of the crown?" The level of satisfaction was rated on two 100-mm visual analogue scales resulting in a score between 0 and 100 corresponding to "very poor aesthetics" and "excellent aesthetics," respectively.

Statistical Analysis

The patient was the statistical unit in all analyses. If more than one single implant had been installed in the same patient, the implant closest to the midline was selected. The Fisher's exact test was adopted to compare the distribution of categorical variables between treatment modalities. The Kruskal-Wallis test was used to compare interval-scaled variables, followed by pairwise Mann-Whitney tests if the resulting p value reached the level of significance. The Wilcoxon signed-ranks test was performed to identify differences between implants and contralateral teeth in terms of clinical conditions. The level of significance was set at 0.05.

RESULTS

One hundred fifteen patients met the selection criteria. One patient passed away and three patients moved. The remainder agreed to come in for evaluation. Two of them cancelled because of illness and five did not show up in the end. Thus, 104/115 patients (43 men, 61

TABLE 2 Reasons for Tooth Loss Sorted per Treatment Modality

Treatment Modality	Reasons for Tooth Loss						Total
	Fracture	Caries/Endodontic	Periodontal	Root Resorption	Agenesis	Unclear	
SIT	9	14	12	1	5	3	44
IIT	10	8	5	2	2	1	28
GBR	3	3	8	2	0	2	18
BGR	7	1	6	0	0	0	14
Total	29	26	31	5	7	6	104

SIT = standard implant treatment; IIT = immediate implant treatment; GBR = guided bone regeneration; BGR = implant treatment in grafted bone.

women; mean age 51; range 22–80) participated for the clinical and radiographic examination corresponding to a response rate of 90%.

Forty-nine SITs had been performed in 44 patients (19 men, 25 women; mean age 52, standard deviation [SD] 13, range 23–76). Thirty-nine subjects received one implant; five patients were provided with two implants. The sample included seven smokers. The mean number of months between implant installation and evaluation was 30 (SD 8, range 17–41).

Thirty IITs had been performed in 28 patients (13 men, 15 women; mean age 51, SD 15, range 25–80). Twenty-six subjects received one implant; two patients were provided with two implants. Five patients were smokers. The mean time from implant surgery to evaluation in this group was 33 months (SD 8, range 17–41).

Nineteen implant treatments in conjunction with GBR had been performed in 18 patients (6 men, 12 women; mean age 53, SD 12, range 25–75). Seventeen subjects received one implant; one patient was provided with two implants. Four patients were smokers. The mean time from implant surgery to evaluation in this group was 30 months (SD 9, range 17–42).

Fourteen BGRs had been performed in 14 patients (5 men, 9 women; mean age 49, SD 14, range 22–64). The sample included two smokers. The mean number of months between implant installation and evaluation was 31 (SD 6, range 19–40).

There was no significant difference between treatment modalities in terms of gender ($p = .798$), age of the patients ($p = .872$), smoking habits ($p = .915$), and time span from implant surgery to evaluation ($p = .394$).

Table 2 shows the reasons for tooth loss sorted per treatment modality. There was no significant difference in the distribution of factors causing tooth failure ($p = .173$). Overall, periodontal disease, fracture, and caries were the most prevalent reasons for tooth loss.

Table 3 shows implant locations sorted per treatment modality. Implant positions differed significantly between SIT and all other modalities ($p \leq .029$) and between IIT and BGR ($p = .020$).

Table 4 provides details on implant diameter and length sorted per treatment modality. There was no significant difference in terms of implant diameter among the groups ($p = .285$). However, for IIT significantly longer implants were used when compared with SIT ($p < .001$) or BGR ($p = .002$).

All but seven crowns were metal-ceramic restorations. Thus, full-ceramic restorations were only installed in a minority of the cases. There was no significant

TABLE 3 Implant Locations Sorted per Treatment Modality

Treatment Modality	Implant Locations				Total
	Central Incisor	Lateral Incisor	Cuspid	Premolar	
SIT	8	7	4	25	44
IIT	11	9	1	7	28
GBR	8	2	4	4	18
BGR	9	0	3	2	14
Total	36	18	12	38	104

SIT = standard implant treatment; IIT = immediate implant treatment; GBR = guided bone regeneration; BGR = implant treatment in grafted bone.

TABLE 4 Distribution of Implants by Diameter and Length

		Length (mm)			
	Diameter (mm)	10	13	16	Total
SIT	3.5	1	5	1	7
	4.3	15	15	4	34
	5	1	2	0	3
	Total	17	22	5	44
IIT	3.5	0	2	1	3
	4.3	1	7	11	19
	5	1	1	4	6
	Total	2	10	16	28
GBR	3.5	1	5	0	6
	4.3	1	6	4	11
	5	0	1	0	1
	Total	2	12	4	18
BGR	3.5	0	3	0	3
	4.3	1	8	1	10
	5	0	1	0	1
	Total	1	12	1	14

SIT = standard implant treatment; IIT = immediate implant treatment; GBR = guided bone regeneration; BGR = implant treatment in grafted bone.

difference in restoration material among treatment modalities ($p = .778$).

Clinical Outcome

In 7/104 patients, one implant was lost pointing to an overall implant survival rate of 93%. All the failures occurred within the first 3 months following surgery without clinical signs of infection and two of them were smokers. Three failures occurred following SIT, two following IIT, one following GBR, and one following BGR.

As shown in Table 5, overall plaque levels were fairly low at implants (24%) and contralateral teeth (26%) indicating good oral hygiene. The difference between implants and teeth was not significant ($p = .389$). However, bleeding on probing was more prevalent around implants when compared with teeth (33% vs 20%, $p \leq .001$). The overall probing depth around implants was 3.2 mm and was also significantly higher than the corresponding value at contralateral teeth (2.7 mm, $p < .001$). There were no significant differences in terms of plaque levels, bleeding on probing, or probing depth between treatment modalities ($p \geq .217$).

Radiographic Outcome

For the analysis of intra- and interexaminer reliability of marginal bone level, we wish to refer to a recent paper.[14] Digital analysis of the radiographs showed mean bone level of 1.19 mm (SD 0.79, range 0.00–5.40) irrespective of the treatment modality. Forty-one percent of the implants showed very limited bone adaptation (bone level ≤ 1 mm); 50% demonstrated moderate bone adaptation (bone level > 1 and ≤2 mm). Nine percent of the implants showed bone levels exceeding 2 mm. Implants installed according to the standard procedure showed mean bone level of 1.12 mm (SD 0.60, range 0.00–2.40). Mean bone level was 1.34 mm (SD 1.17, range 0.12–5.40), 1.10 mm (SD 0.54, range 0.25–2.05), and 1.30 mm (SD 0.64, range 0.50–2.62) for IIT, GBR, and BGR, respectively. There was no significant difference between the groups ($p = .905$) (Figure 5).

The actual bone loss that was calculated for 38 cases yielded 1.20 mm on average (SD 0.85, range 0.00–4.80). Mean marginal bone level for these cases was 1.26 mm (SD 0.92, range 0.00–5.40). Bone loss and bone level showed high correlation (Pearson's correlation: 0.982, $p < .001$). However, the disparity between bone loss and bone level was of borderline significance ($p = .055$).

Complications

Four out of 44 patients treated according to the standard procedure expressed at least one *postoperative complication*. The prevalence of such complications was 5/28, 11/18, and 13/14 following IIT, GBR, and BGR, respectively. Thus, the risk for at least one postoperative complication was significantly associated with the treatment modality with higher risk following GBR/BGR (>61%) when compared with SIT/IIT (<18%) ($p < .001$).

Two patients experienced *infectious complications*. Membrane exposure occurred in one patient treated by means of GBR. At the time of inspection, a fistula was found in another patient who received an immediate implant, which was probably related to the presence of cement remnants. There was no significant difference between treatment modalities ($p = .093$).

Nine patients experienced *technical complications*: six crowns lost retention and three porcelain fractures occurred. There was no significant difference between treatment modalities ($p = .445$).

None of the patients experienced *permanent complications* except for four patients in the BGR group. The disparity in the prevalence of such complications was

TABLE 5 Comparison of Clinical Parameters between Implants and Contralateral Teeth

		Implant	Contralateral Tooth
Plaque (%)	Mean (SD)	24 (19)	26 (21)
	Minimum	0	0
	Maximum	75	75
Bleeding on probing (%)	Mean (SD)	33 (20)	20 (20)
	Minimum	0	0
	Maximum	75	75
Probing depth (mm)	Mean (SD)	3.2 (0.7)	2.7 (0.5)
	Minimum	1.5	2.0
	Maximum	5.0	4.8

SD = standard deviation.

highly significant between BGR and any other treatment modality ($p < .001$). Three patients reported minor hypoesthesia of the soft tissues of the chin and one patient experienced reduced sensitivity of the lower incisors. One of them was endodontically treated.

All patients would undergo the same treatment again except for two patients in the BGR group showing permanent complications. The disparity with any other treatment modality was significant ($p = .017$).

Aesthetic Outcome

For the analysis of intra- and interexaminer reliability of PES and WES, we wish to refer to a recent paper.[20] Table 6 shows the results of all seven criteria of the PES sorted per treatment modality. Significantly lower distal papillae were found following advanced reconstructive surgery (overall $p = .009$; GBR – IIT: $p = .015$; BGR – SIT: $p = .022$; BRG – IIT: $p = .045$). That is, incomplete distal papillae were more probable following GBR/BGR when compared with SIT/IIT (odds ratio [OR] 4.3, 95% confidence interval [CI] 1.6–11.4, $p = .004$). Papillae were also highly related to the reason for tooth loss with higher probability of incomplete papillae when the tooth was lost because of periodontal disease (OR: 13.0, 95% CI 3.6–47.6, $p < .001$). In addition, incomplete distal papillae were more likely in patients with a thin-scalloped gingival biotype (OR: 3.7, 95% CI 1.3–10.5, $p = .011$). There was a significant treatment effect with respect to soft tissue aesthetics ($p = .045$). Mean PES was significantly lower following BGR when compared with IIT ($p = .018$). The best and worst cases per treatment modality are illustrated in Figures 6 and 7. Mean WES was 7.98 (SD 1.67, range 3–10) for all patients considered.

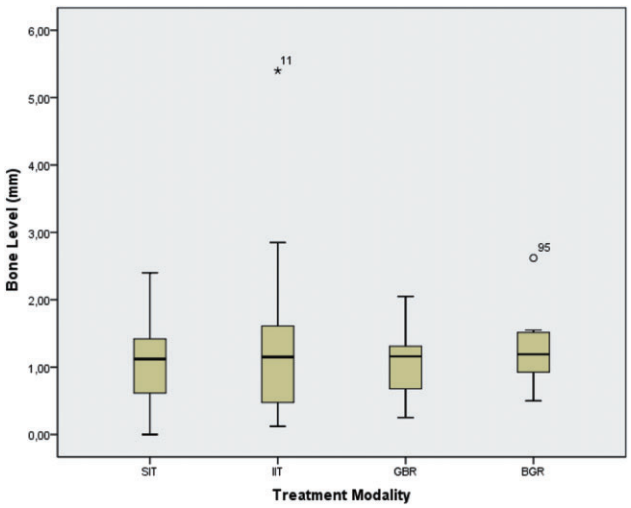

Figure 5 Boxplots illustrating bone level per treatment modality. Note one outlier for IIT and one extreme value for BGR.

Patient's Aesthetic Satisfaction

Mean patient's pink aesthetic satisfaction was 92 (SD 8, range 69–100) for all patients considered. A weak, yet significant correlation was found with PES (Spearman's correlation 0.246, $p = .016$). Mean patient's white aesthetic satisfaction was 93 (SD 8, range 67–100) for all patients considered. A weak, yet significant correlation was found with WES (Spearman's correlation 0.267, $p = .015$) (Figure 7).

DISCUSSION

To our knowledge, this is the first clinical study documenting four routine modalities of single implant treatment in the anterior maxilla based on consecutively

TABLE 6 Aesthetic Outcome of Single Implants Sorted per Treatment Modality

	SIT ($n = 41$)			IIT ($n = 26$)			GBR ($n = 17$)			BGR ($n = 13$)			
	0	1	2	0	1	2	0	1	2	0	1	2	*p* Value
Mesial papilla	2	15	24	3	8	15	3	7	7	3	7	3	.180
Distal papilla	3	16	22	3	7	16	1	12	4	5	5	3	.009
Midfacial level	2	16	23	2	4	20	2	3	12	2	4	7	.257
Midfacial contour	4	15	22	1	10	15	1	10	6	1	6	6	.740
Alveolar process deficiency	8	14	19	4	7	15	2	4	11	0	4	9	.633
Soft tissue color	1	21	19	2	5	19	0	8	9	0	8	5	.064
Soft tissue texture	2	20	19	1	8	17	3	6	8	1	7	5	.346
PES	**10.07 (1.96) [6–13]**			**10.88 (2.41) [6–14]**			**9.65 (2.23) [4–13]**			**9.00 (1.73) [5–11]**			**.045**

PES (mean) [range].
SIT = standard implant treatment; IIT = immediate implant treatment; GBR = guided bone regeneration; BGR = implant treatment in grafted bone.

treated patients in daily practice by the same clinicians. Even though this was a retrospective study, the homogeneity in terms of care providers, implant system, biomaterials, follow-up, and the fact that all clinical conditions were included going from straightforward to complex cases could be considered unique. As a result, we believe that this report may add relevant information to the existing knowledge on the outcome of single implant treatment.

In this investigation, implant survival was 93%, which is slightly lower than what would be expected after two and a half years of function for single implants with an oxidized surface.[21–23] This may be due to real life clinical practice as opposed to academic environments where patients are carefully selected and strictly monitored for prospective studies. On the other hand, all patients received prophylactic antibiotics for implant surgery in this study. There is some evidence from a recent systematic review suggesting reduction of failure by such administration.[24]

Our results did not reveal a disparity between implants installed in native bone and regenerated/

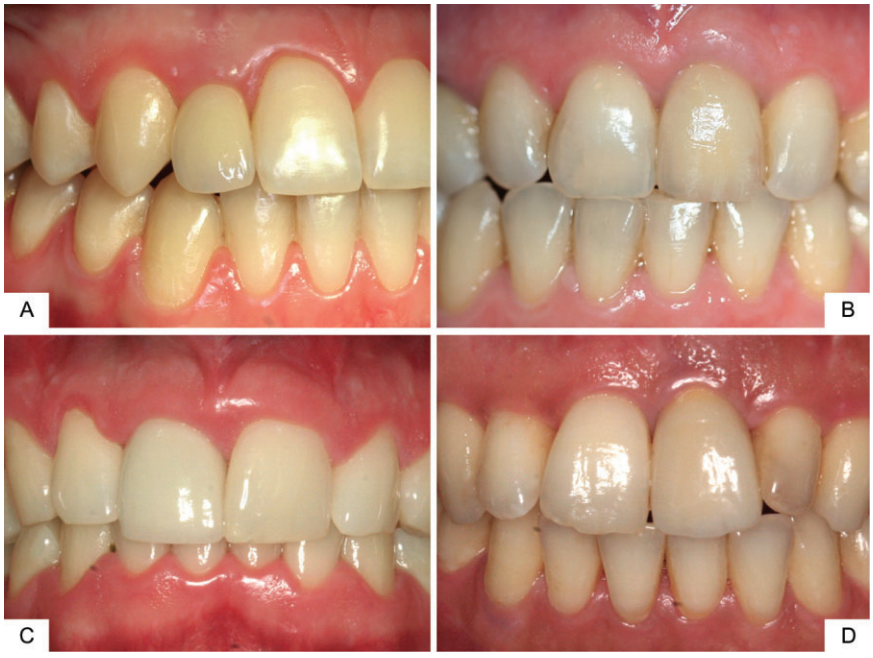

Figure 6 Cases with the best aesthetic outcome per treatment modality. SIT. Implant location: 12 (A). IIT. Implant location: 21 (B). GBR. Implant location: 11 (C). BGR. Implant location: 21 (D). BGR = implant treatment in grafted bone; GBR = guided bone regeneration; IIT = immediate implant treatment; SIT = standard implant treatment.

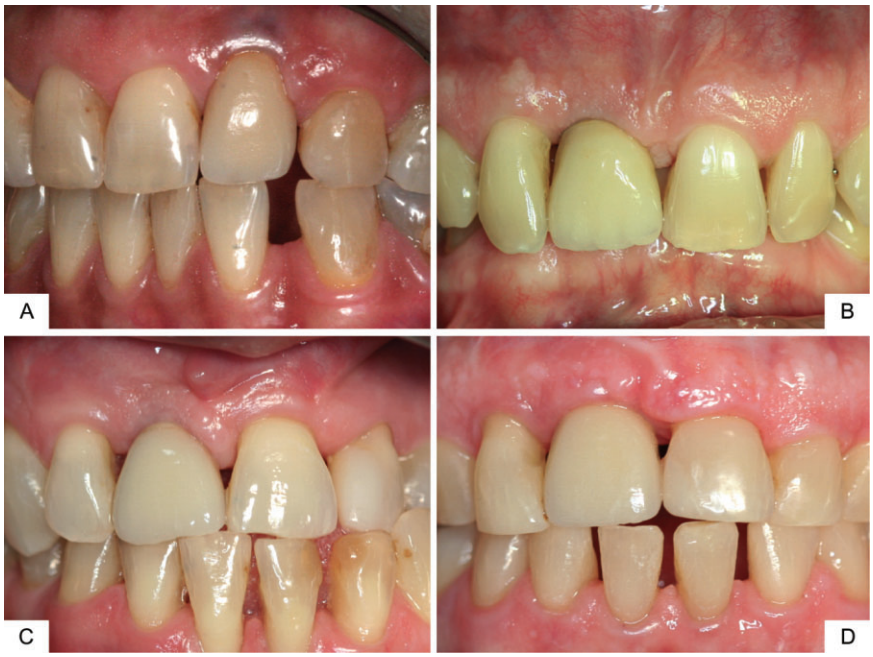

Figure 7 Cases with the worst aesthetic outcome per treatment modality. SIT. Implant location: 22 (A). IIT. Implant location: 11 (B). GBR. Implant location: 11 (C). BGR. Implant location: 11 (D).

grafted bone, which is in agreement with a recent multifactorial analysis on implant failure in a large study sample.[25]

In our patients, plaque levels were fairly low at implant and corresponding tooth sites, indicative of good oral hygiene. Bleeding on probing and probing depth were significantly higher around implants when compared with contralateral teeth, which has been earlier explained by the development of an inflammatory cell infiltrate near the implant-abutment interface.[26,27] An important observation was that implants with an oxidized surface clinically performed well in this study irrespective of the treatment modality.

One of the outcome variables of interest in this study was marginal bone level. Actual bone loss could be calculated on a subset of the data. The fact that the disparity between bone loss and bone level was of borderline significance indicates a trend toward a systematically higher value for bone level. These findings suggest that bone level is an appropriate surrogate for bone loss that slightly tends to overrate it. Overall, mean bone level yielded 1.19 mm with no significant differences among the treatment modalities. This observation indicates acceptable bone adaptation around implants with an oxidized surface, which is in agreement with the existing knowledge on such implants installed in native bone after at least 2 years of function.[21–23] Still, 9% of our implants showed >2 mm bone level, which is relatively high. Whether this observation is a result of physiological variation or an early sign of peri-implantitis around an implant surface possibly prone to the condition[28–30] is unclear. As the latter has only been demonstrated in preclinical studies, a reexamination of our patients after at least 5 years of function would be meaningful.

Of particular importance was the prevalence of complications in this study. Postoperative complications were significantly more common following GBR/BGR, which may be related to wide flap elevation with vertical incisions beyond the mucogingival junction, release of the periosteum, and a second surgical site for bone harvesting (nasal spine or chin). Only two patients had infectious complications that could be resolved by local therapy. However, the prevalence of technical complications was clearly higher with nine patients experiencing porcelain fractures or crown loosening. Such high prevalence is in agreement with at least two systematic reviews.[31,32] Four patients showed permanent complications, all following BGR. These were minor sensory problems relating to the donor site. Given the long treatment period and such complications, two of these patients would not undergo the same treatment again given their experience. The available literature on the prevalence of enduring sensory complications following bone grafting from the chin shows high variability ranging from no

permanent impact[33] to a permanent impact in about half of the patients.[34,35] The medium risk described on the basis of our data is in agreement with a number of other studies.[36–39] Differences may be explained by variability in the position of incisions and bone cuts.

Most interesting were the results on soft tissue aesthetics in this study. SIT and IIT did not differ significantly in this respect, which is in agreement with Raes and colleagues.[40] However, one should keep in mind that patients were carefully selected for IIT, hereby excluding high-risk patients with a thin-scalloped gingival biotype. Given the significant distortion in terms of this parameter, the gingival biotype could be considered a confounder. On the other hand, significantly more premolar replacements were performed by means of SIT. As these may be less delicate than incisor replacements from an aesthetic point of view,[20] implant location could also be considered a confounder, yet in favor of SIT. Following SIT as well as IIT, the alveolar process scored worst from all criteria showing major deficiency in >15% of the cases. Efforts to prevent this could include ridge preservation and/or connective tissue grafting. Especially with respect to the latter, the available literature is scarce and focuses on midfacial recession.[41,42] Prospective studies are needed to investigate the stability of connective tissue grafts in the horizontal dimension.

When comparing the aesthetic outcome of the four modalities, advanced reconstructive surgery, especially BGR, showed inferior results. Also, Meijndert and colleagues[43] and den Hartog[44] commonly found compromised aesthetics following BGR. In our study, mainly short distal papillae were responsible for this outcome. Reduced papillae were also a frequent finding following GBR in another investigation.[10] Detailed analyses based on the present material showed that periodontal disease (OR: 13.0), GBR/BGR (OR: 4.3), and a thin-scalloped gingival biotype (OR: 3.7) increased the risk for incomplete distal papillae. These findings suggest that the etiology of papilla loss is multifactorial. How GBR/BGR contribute to this phenomenon is not well understood. The incision technique including both papillae has been suggested as a possible cause,[9] however papillae were also elevated for SIT and IIT in this study. Most likely, the number of surgical interventions with possible repeated papilla elevation is more relevant in this respect. We performed one intervention for IIT, two for SIT, and three for GBR/BGR. One should also take into account a possible disparity in the starting point between SIT/IIT and GBR/BGR. Cases treated by means of GBR/BGR demonstrated a buccal bone defect that could have included the interproximal area to some extent. Given the aforementioned risk for complications and compromised aesthetics following advanced reconstructive surgery, research is required on the prevention and treatment of buccal bone defects at the time of tooth loss.

As the original condition determines the treatment trajectory, it is logic that the starting point was not the same between the groups prior to implant treatment. Indeed, hard tissue deficiency needs to be treated prior to or during implant surgery, whereas sufficient bone volume allows for a standard or even immediate approach. Such a disparity at baseline could be considered a restriction when it comes to comparing treatment outcomes, at least from a pure scientific point of view. On the other hand, it is of the utmost importance from a clinical point of view to know whether comparable outcomes are realistic following complex (GBR/BGR) and innovative (IIT) treatment concepts in reference to a standard approach (SIT). After all, the primary expectation will be a – close to – perfect restoration and any preexisting limitation to accomplish that goal may be of secondary concern for the patient.

At the time the patients of the present study were treated, surgery was mainly driven by hard tissue conditions. Consequently, almost every single implant case was treated according to one of the four treatment modalities described and therefore this report may provide a quite complete view on the outcome of routine single implant treatment, at least in our clinical setting of 2006 to 2007. Ever since, implant dentistry has been evolving and treatment protocols have also changed in our center. As a result, contemporary single implant treatment includes more ridge preservation and connective tissue grafting via flapless or papilla saving procedures. Especially IIT is nowadays performed via flapless surgery, which has been shown to limit midfacial recession.[40] Note that all these innovations were not considered here and that the few cases treated as such were excluded.

In the present study, a trained clinician evaluated the aesthetic outcome using objective criteria. Also patients expressed their satisfaction in terms of aesthetics. Poor agreement was found between objective and subjective ratings. Overall, patients seem less critical than clinicians in evaluating aesthetics, which confirms earlier findings.[43,45,46]

In conclusion, the four treatment modalities under investigation were predictable from a clinical and radiographic point of view. However, advanced reconstructive surgery, especially BGR, increased the risk for complications and compromised aesthetics. Mainly short distal papillae were responsible for the latter. Research is required on the prevention and minimally invasive treatment of buccal bone defects at the time of tooth loss to avoid complex therapy.

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