Clinical, Aesthetic, and Patient-Related Outcome of Immediately Loaded Single Implants in the Anterior Maxilla: A Prospective Study in Extraction Sockets, Healed Ridges, and Grafted Sites

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ABSTRACT

Purpose: The objective of this prospective clinical study was to document the overall treatment outcome of immediately loaded single Astra Tech Osseospeed™ (Astra Tech AB, Mölndal, Sweden) implants placed in extraction sockets, healed ridges, and grafted sites.

Materials and Methods: Forty-eight patients in need of a single implant in the anterior maxilla (15–25) were recruited. Patients were allocated to a conventional implant treatment (CIT) or immediate implant treatment (IIT) group on the basis of specific criteria. If the buccal bone plate was damaged or missing upon tooth removal, patients were allocated to a grafted implant treatment (GIT) group. Irrespective of the treatment concept, implants were immediately provisionalized. Hard and soft tissue alterations, aesthetic parameters (pink and white esthetic scores, [PES and WES]) and patient's opinion (Oral Health Impact Profile [OHIP-14] questionnaires) were registered at different time points.

Results: After 1 year of function, the overall implant survival rate was 98% with one failure following IIT. The mean bone level to the implant-abutment interface was 0.65 (SD 0.79), 0.85 (SD 0.64), and 0.56 mm (SD 0.44) for CIT, IIT, and GIT. Complete papilla loss was rare following either strategy. Mean midfacial recession amounted to 1.00 (SD 1.15), 0.12 (SD 0.78), and 0.49 mm (SD 0.82) for CIT, IIT, and GIT, respectively. The aesthetic outcome showed a mean PES of 10.30 (SD 1.89) and mean WES of 7.11 (SD 2.14), all patients considered. Patient's satisfaction showed a significant improvement after 1 year of function on all seven domains ($p < .001$).

Conclusions: This prospective study showed that single implants clinically and aesthetically perform well under immediate non-occlusal loading conditions in the premaxilla. In this context, it is of pivotal importance to stress that patients were carefully selected for IIT and GIT.

KEY WORDS: immediate loading, implant protocol, single implants

INTRODUCTION

A range of loading schedules have been described in implant dentistry including immediate, early, conventional, and delayed loading of implants.[1,2] Immediate loading has been reported successful predominantly for

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multiple-splinted implants in the interforaminal region of the mandible[3–7] and the maxilla.[8–10] Single maxillary implants in the anterior maxilla may also be immediately restored with predictable osseointegration and high implant survival rates ranging from 96 to 100%.[11–18] Proper primary implant stability and avoidance of occlusal or eccentric contact during the healing period have been considered prerequisites for success in this respect.[12,19,20] A recent meta-analysis reported on the outcome of various loading protocols for single implants and demonstrated no significant impact of this parameter.[20] However, it was stated that the available literature pertaining to soft tissue aspects and aesthetics was scarce. We believe that soft tissue aspects may be important in treatment planning. For one thing, patients with a so-called thin-scalloped gingival biotype have been found at risk for possible aesthetic complications.[21–23] As a result, clinicians may want to exclude these patients for high-risk procedures such as immediate placement and provisionalization. The same applies for sites with reduced bone volume or anatomic restrictions (dehiscence or fenestration). These defects need bone reconstruction for a predictable outcome in the long term. Clearly, proper risk assessment and simplicity lead to the temporal separation of bone augmentation and implant placement procedures. Recent developments have suggested socket grafting at the time of tooth loss in order to avoid extensive bone reconstruction thereafter.[24,25] Such ridge preservation is a simple and minimally invasive technique using anorganic bovine bone material and a resorbable occlusive membrane, which involves less risk for complications. With respect to the aesthetic outcome of single-implant restorations, objective evaluation criteria have recently been described. The Pink Esthetic Score (PES) was introduced by Furhauser and colleagues[26] and includes factors relating to the soft tissues, whereas the White Esthetic Score (WES) by Belser and colleagues[27] relates to the quality of the implant crown.

Another aspect of treatment outcome is patient's opinion, which may be explored by oral health quality of life questionnaires. Overall, only 2% of the available literature on implant treatments reported on patient-centered outcomes,[28] and for single-tooth replacement, very few articles have ever addressed the issue.[29]

To our knowledge, there are no clinical studies available on three routine modalities of single-implant treatment based on consecutively treated patients in daily practice by the same clinicians. Given the aforementioned, the objective of this clinical study was to document the overall treatment outcome of immediately loaded implants placed in extraction sockets, healed ridges, or grafted sites with an emphasis on soft tissue aspects, aesthetic parameters, and patient's opinion.

MATERIALS AND METHODS

Patient Selection

The data pertaining to this paper all relate to patients in need of a single implant in the anterior maxilla,[15–25] who were recruited in the dental clinic of the University Hospital in Ghent according to particular inclusion and exclusion criteria (Figure 1). Immediate implantation was never performed in high-risk patients with a thin-scalloped gingival biotype as determined by the transparency of the periodontal probe through the gingival margin while probing the buccal sulcus of the upper central incisor.[30] Other clinical parameters to include patients were ideal soft tissue level and contour at the facial aspect of the failing tooth or the single-tooth gap, implying no visible disparity between the latter and the contralateral tooth and the adjacent teeth as described in a previous paper.[18] All patients signed an informed consent before treatment. 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 of Ghent (UZ Ghent, no. 2004/439).

Treatment Groups

After clinical examination and according to the clinical condition, patients were allocated to a conventional implant treatment (CIT) or immediate implant treatment (IIT) group. In both groups, panoramic radiographs (Cranex Tome multimodal X-ray unit, Soredex, Tuusula, Finland), standardized periapical radiographs (Gendex Oralix AC Densomat, Kavo Dental®, Gendex Imaging, Cusano Milanino, Milan, Italy), and cone beam computed tomography (CT) (i-CAT®, Imaging Sciences International®, Hatfield, PA, USA) were taken prior to inclusion. At that moment, bone quantity and quality were assessed. All cases were screened and, if necessary, treated for caries, endodontic, or periodontal infections. Upon surgical evaluation of either the healed alveolar ridge or the resulting extraction socket, clinical decisions were made whether or not an

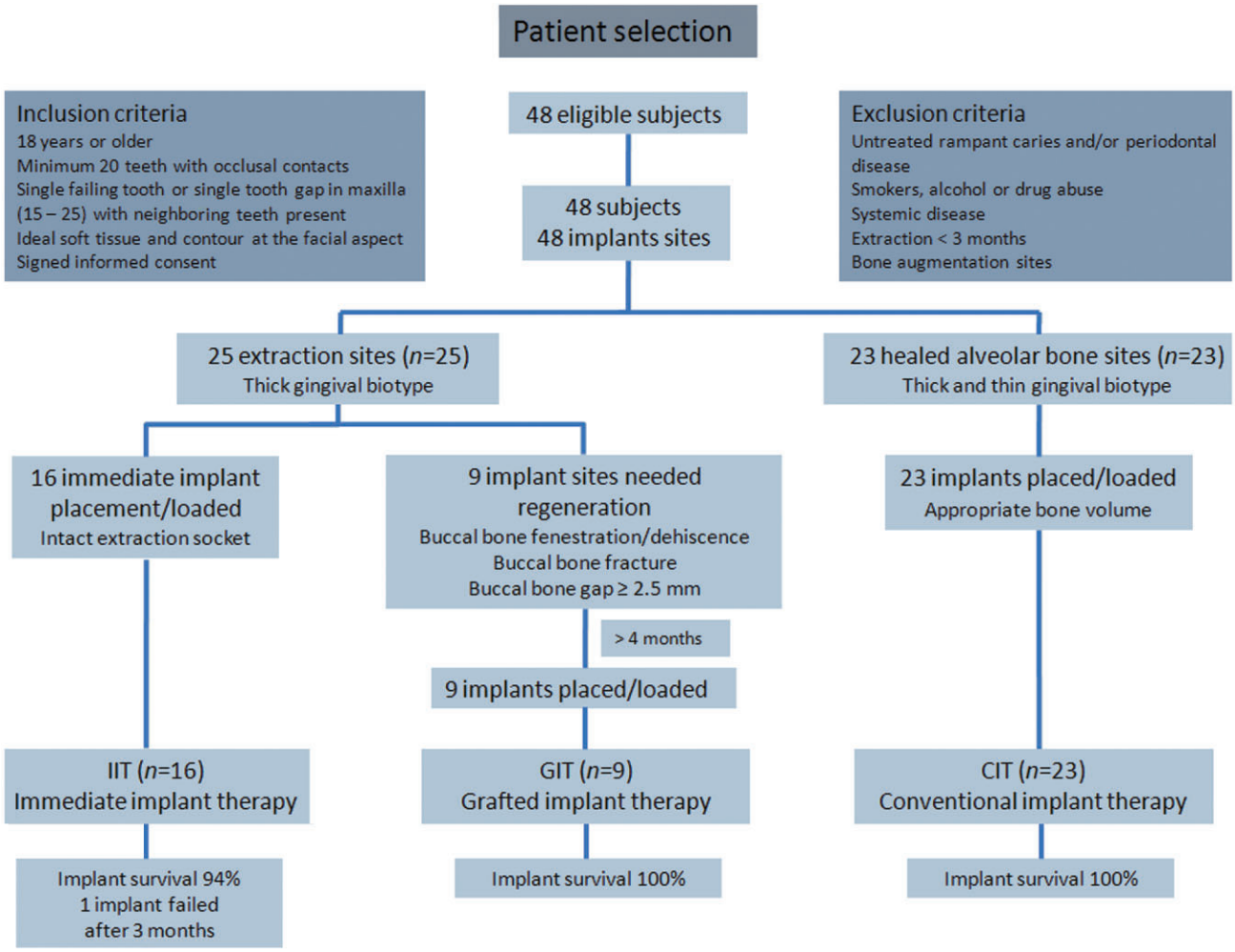

Figure 1 Flow chart with inclusion and exclusion criteria and patient selection with eligible subjects.

implant could be placed and immediately provisionalized. The adequate dimension of available alveolar bone and, for sockets, the presence of an intact buccal plate of bone was an initial prerequisite for implant placement. Additionally, unforeseen infections, bony defects, damage to the buccal bone plate, and/or soft tissues, <3 mm residual apical native bone to stabilize the implant, and the implant-to-bone distance ≥2.5 mm were considered contraindications for immediate implant placement. If however, implant placement was not possible at this time, guided bone regeneration was performed using anorganic bovine bone (Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland) and a resorbable collagen membrane (Bio-Gide®, Geistlich Pharma AG). These patients were allocated to a third treatment group, the grafted implant treatment (GIT) group, and received an implant 4 to 5 months thereafter.

Implant Placement, Provisonalization, and Final Crown Delivery

The treatment modalities for implant (Astra Tech Osseospeed™, Astra Tech AB, Mölndal, Sweden) placement, provisonalization, and final crown delivery are described in detail in previous publications.[17,18] Clinical cases relating to IIT, CIT, and GIT groups are illustrated in Figures 2–4, respectively. Flapless or different flap techniques limited to crestal incision or extended to full-thickness flap reflection were used.

Hard and Soft Tissue Response

To evaluate the hard tissue response over time, periapical radiographs using the long cone paralleling technique, were made at baseline (day of implant/provisional crown placement), 4, 12, 26, and 52 weeks. An X-ray holder (XCP Bite Block, Dentsply® Rinn, Elgin, IL, USA) was used and individualized with an occlusal resin jig

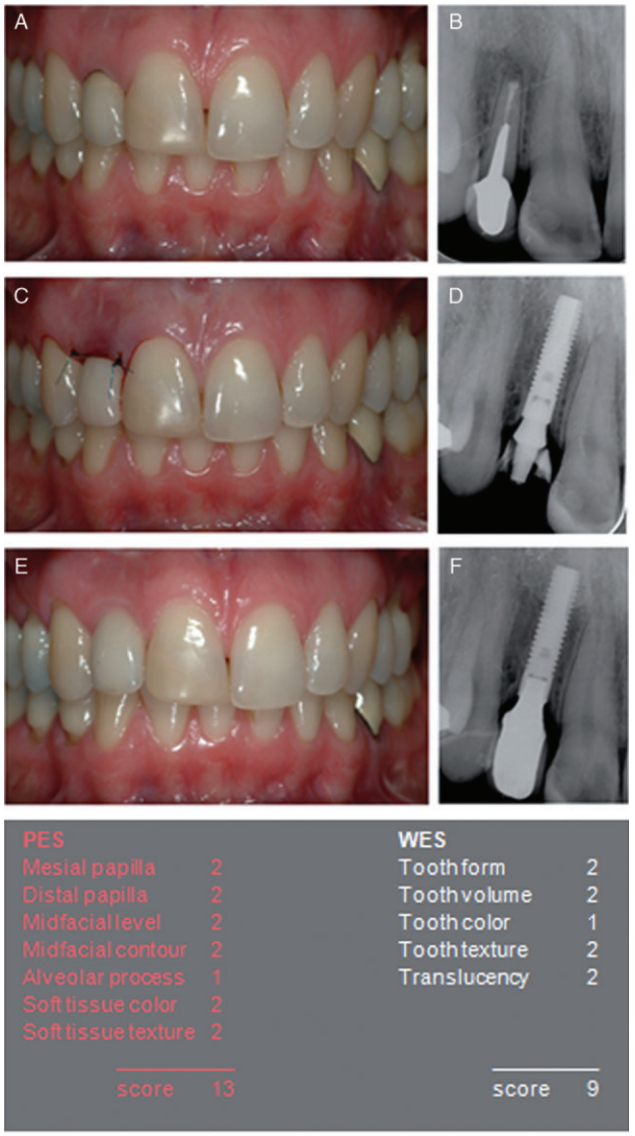

Figure 2 Immediate implant treatment case. *A* and *B*, Endodontic involved right lateral incisor with favorable soft tissue dimensions. *C* and *D*, Immediate implant with Direct Abutment™ (Astra Tech AB) and immediate provisionalization adapted with radiopaque Filtek™ Supreme XTE Flowable composite (3MBelgium, Diegem, Belgium). *E* and *F*, One year result with zirconium abutment and cemented full-ceramic crown.

(Tempron GC, Aichi, Japan) to standardize the angulation and position of the film (Kodak® E-F speed dental film, Carestream Dental AB, Kista, Sweden) in relation to the implant and the X-ray beam and to minimize the geometric magnification in the periapical image. An independent radiologist not affiliated to the study center performed all radiographic interpretations. The distance from the mesial and distal interproximal bone to the reference point (outer aspect of the implant bevel) was measured to the nearest 0.1 mm under seven times magnification using a magnifying glass and ideal illuminance and dimmed room circumstances. The mean of these two measurements was calculated for each implant, and the changes from baseline were calculated for all follow-up periods. At the above-mentioned time points, the clinical condition of the peri-implant soft tissues was evaluated by monitoring the presence or absence of plaque and by probing the peri-implant sulcus to register possible bleeding at four sites (mesiobuccal [MB], distobuccal [DB], mesiolingual [ML], and distolingual [DL]).

The midfacial mucosa level (linear distance from the mucosal zenith to the incisal reference line) and the papilla score (linear distance from the papilla tip to the incisal reference line) were recorded on continuous standardized digital slides using appropriate software (Gingival Status 2009 1.0.0.2., Inspector BV, Baarn, the

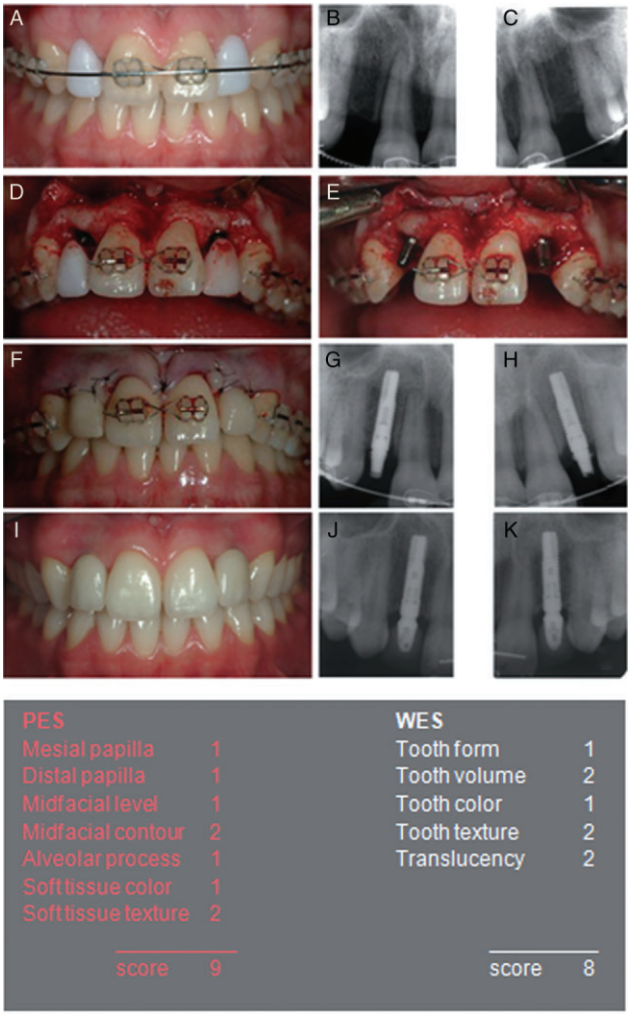

Figure 3 Conventional implant treatment case. *A–C*, Bilateral congenital missing lateral incisors. *D* and *E*, Osseospeed™ implant and Direct Abutment™. *F–H*, Immediate provisionalization. *I–K*, One year result with Ti-Design™ abutment (Astra Tech AB) and cemented full-ceramic crown.

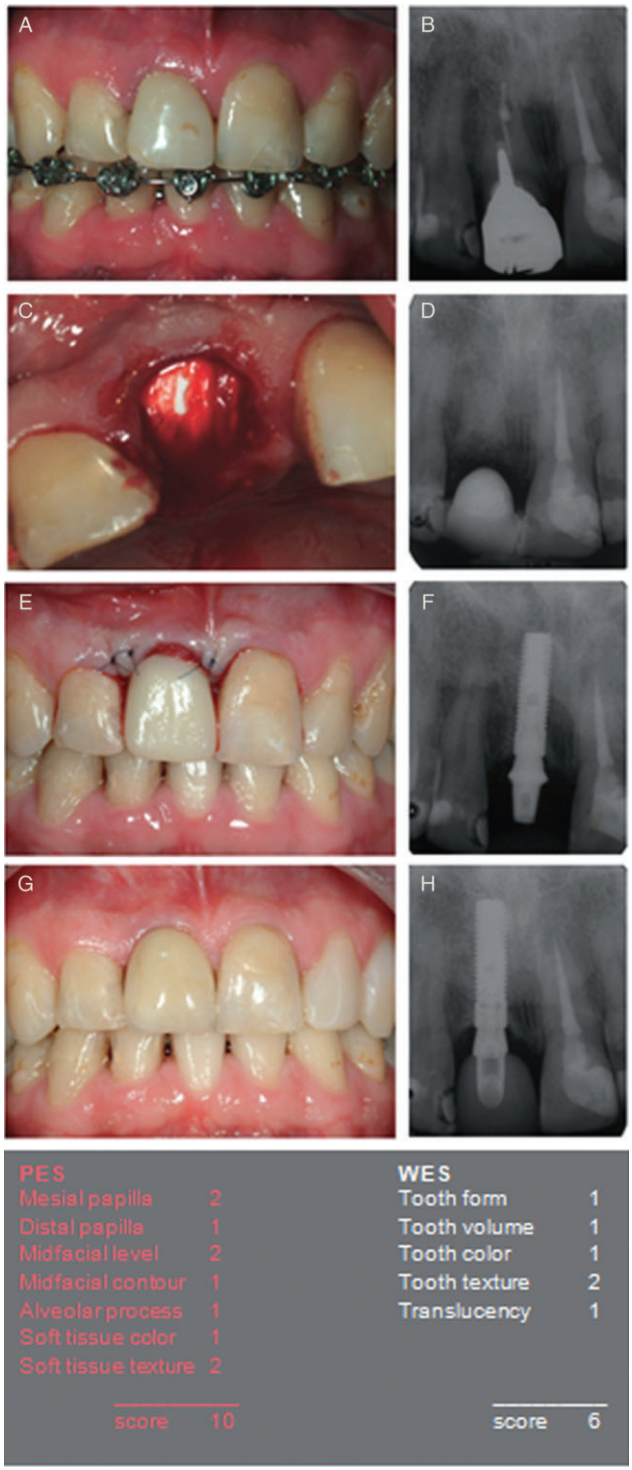

Figure 4 Grafted implant treatment case. *A* and *B*, Endodontic involved right central incisor with favorable soft tissue dimensions. *C* and *D*, Extraction and grafting of extraction socket with Bio-Oss® and Biogide® and >4 months healing period and temporization with splint. *E* and *F*, Implant placement and immediate provisionalization. *G* and *H*, One year result with Ti-Design™ (Astra Tech AB) abutment and cemented full-ceramic crown.

Netherlands) as described in a previous article.[18] Provisional crown cementation was considered baseline. Slides were made at baseline, 4, 12 (final crown cementation), 26, and 52 weeks. The changes from baseline were calculated for all follow-up periods.

Aesthetics

After 1 year (52 weeks after day of implant/crown placement), the PES and WES were registered according to the technique described by others.[26,27]

Patient Satisfaction

Patient satisfaction was measured using the Dutch validated version of the Oral Health Impact Profile (OHIP-14) questionnaire,[31] which is a shortened version of the OHIP-49 questionnaire.[32,33] This questionnaire captures seven conceptually formulated dimensions in 14 questions that are based on Locker's theoretical model of health.[34] Two questions per domain reflect on: functional limitation, physical pain, psychological disability, physical disability, psychological discomfort, social disability, and handicap. The questions are answered on a scale from 1 to 5. Five is defined as the maximal positive result indicative of total absence of problems; 1 corresponds to the maximal negative answer or always a problem. (Answers: 1 = "very often," 2 = "fairly often," 3 = "occasionally," 4 = "hardly ever," and 5 = "never"). Clinicians involved in surgery and/or prosthetics were not present when the patient was filling in the OHIP questionnaire. The questionnaire was completed at intake before surgery and 4, 26, and 52 weeks after implant placement and immediate provisionalization.

Statistical Analysis

Data analysis was performed using the patient as the statistical unit, and descriptive statistics were used to analyze the group characteristics. Because of the limited sample size, nonparametric tests were adopted. Bone level, soft tissue, and OHIP-14 scores changes over time within each group were examined using the Friedman test. If a significant time effect was found, Wilcoxon signed-ranks tests were performed comparing the different time points two by two. The level of significance was set at .05 for each test.

RESULTS

Forty-eight patients were recruited and demographic details are provided in Table 1. Of 25 patients selected for

TABLE 1 Demographic Features of Patients

Treatment Strategy	*n*	Gender, *n* (%)	Male Age, Mean (SD, Range)	Female Age, Mean (SD, Range)	Total Age, Mean (SD, Range)	Ex-Smoker, *n* (%)
IIT	16	10 males (62), 6 females (38)	44 (15, 28–68)	46 (15, 22–67)	45 (14, 22–68)	0 (0)
CIT	23	12 males (52), 11 females (48)	49 (19, 19–75)	30 (12, 19–52)	40 (19, 19–75)	2 (9)
GIT	9	5 males (56), 4 females (44)	32 (10, 20–47)	39 (21, 22–69)	35 (15, 20–69)	2 (22)

IIT = immediate implant treatment; CIT = conventional implant treatment; GIT = grafted implant treatment.

immediate implant placement and provisionalization, 16 were treated (IIT) ($n = 16$ sites). Nine patients (36%) revealed insufficient bone according to the protocol, and implant placement was postponed until 4 to 5 months after grafting. These sites were excluded during surgery because of buccal bone dehiscence and/or fenestration and allocated to the grafted group (GIT). Among the 23 patients selected for implant placement in a healed ridge ($n = 23$ sites), all patients had sufficient bone for implant placement, and none were allocated to grafting (see Figure 1). The reasons for tooth loss are shown in Table 2. Caries/endodontic lesions and tooth fractures were the most prevalent reasons for tooth failure in the three groups. The distribution of implants is depicted in Table 3. Overall, lateral incisors and premolars had to be replaced most often. The dimension of implants selected for treatment ranged from 3.5 to 5.0 mm in diameter and 11 to 17 mm in length (Table 4).

Surgical Approach

In the IIT group, 11/16 patients were treated via a flapless approach, none in the CIT group, and 2/9 in the GIT group. In the CIT group 18/23 (78%) cases were treated with a full-thickness mucoperiosteal flap. A minimal crestal incision was used in 5/23 CIT cases and 7/9 GIT cases. There were no exclusions in any of the groups because of insufficient insertion torque. In all the cases, primary stability was achieved during implant placement and all implants received a provisional crown at the planned treatment visit.

Survival and Hard Tissue Response

For the 48 patients included in the study, 47 patients had their implant at the 1-year reassessment in function (implant survival 98%). In the extraction socket group, one implant failed after 3 months (implant survival 94%), which was later on replaced by a conventional three-unit bridge. There were no dropouts.

Changes of the interproximal marginal mean bone level for IIT, CIT, and GIT are shown in Table 5. A trend toward bone gain of 1.05 mm (SD 1.78, range −1.15–4.00) ($p = .248$) was observed in the IIT group from baseline to 1 year of function. An interproximal change of marginal bone levels of −0.18 mm (SD 1.26, range −3.15–2.40), and 0.27 mm (SD 1.26, range −0.35–1.65) after 1 year was observed in the CIT and GIT group, respectively. At 1 year, bone levels (relative to reference point) were on average 0.65 (SD 0.79, range 0.00–3.15), 0.85 (SD 0.64, range 0.00–2.30), and 0.56 mm (SD 0.44, range 0.00–1.50) for CIT, IIT, and GIT, respectively.

Soft Tissue Response

The entire study population showed no bleeding on probing after 1 year in 83% (39/47) of the implants.

TABLE 2 Reasons for Tooth Loss Sorted per Treatment Strategy

Treatment Strategy	Agenesis	Fracture	Caries/Endodontic	Periodontal	Root Resorption	Total
IIT	N/A	5	7	1	3	16
CIT	8	5	6	3	1	23
GIT	N/A	3	4	0	2	9
Total	8	13	17	4	6	48

IIT = immediate implant treatment; CIT = conventional implant treatment; GIT = grafted implant treatment.

TABLE 3 Implant Position per Treatment Strategy

Treatment Strategy	Implant Position				Total
	Central Incisor	Lateral Incisor	Canine	Premolar	
IIT	3	5	2	6	16
CIT	3	10	1	9	23
GIT	4	1	0	4	9
Total	10	16	3	19	48

IIT = immediate implant treatment; CIT = conventional implant treatment; GIT = grafted implant treatment.

Eight implants out of 47 (17%) demonstrated one bleeding site. Eighty-five percent (40/47) of the implants showed no plaque, 11% (5/47) one site of plaque, and 4% (2/47) two sites of plaque after 1 year.

The average change over time in papilla dimension at mesial and distal sites are summarized in Table 5. Mesial papillae remained stable over time in all groups. In IIT, distal papillae showed shrinkage of 0.38 mm (SD 1.21) after 1 year of function.

Midfacial soft tissue level was monitored throughout the study period following provisional crown installation (see Table 5). For IIT and GIT, the average midfacial level reflected a stable position after 1 year. However, CIT revealed a significant recession of 1.00 mm (SD 1.15). At the final reassessment, advanced midfacial recession (>1 mm) was found in 7% of immediately installed implants, respectively 43% of conventionally installed implants and in 22% of the implants installed in grafted sites. Major soft tissue gain (>1 mm) was found in 13% of the IIT cases, respectively none of the CIT and GIT cases.

The impact of the gingival biotype on soft tissue response was explored for the three groups. The gingival biotype was neither associated with papilla loss ($p \geq .082$) nor with midfacial recession ($p \geq .280$).

Aesthetics

Table 6 shows the results of all criteria of the PES per treatment strategy. The mean PES was 10.33 (SD 2.29, range 6–14), 10.35 (SD 1.58, range 7–13), and 10.11 (SD 2.09, range 7–14) for IIT, CIT, and GIT, respectively. Twenty-five percent of the cases could be considered (almost) perfect (PES ≥ 12 as arbitrarily defined by Cosyn and colleagues[23]). About 10% of all cases were

TABLE 4 Implant Length and Diameter Sorted per Treatment Strategy

Treatment Strategy	Diameter	Length				Total
		11	13	15	17	
IIT	3.5	0	0	0	0	0
	4	0	0	2	3	5
	4.5	0	1	4	1	6
	5	0	0	2	3	5
CIT	3.5	0	4	5	1	10
	4	1	3	3	5	12
	4.5	1	0	0	0	1
	5	0	0	0	0	0
GIT	3.5	0	0	0	0	0
	4	0	2	4	1	7
	4.5	1	0	1	0	2
	5	0	0	0	0	0
Total		3	10	21	14	48

IIT = immediate implant treatment; CIT = conventional implant treatment; GIT = grafted implant treatment.

TABLE 5 Hard and Soft Tissue Changes in Relation to Baseline Sorted per Treatment Strategy

	Treatment Strategy	4 Weeks, Mean (SD) [Range]	12 Weeks, Mean (SD) [Range]	26 Weeks, Mean (SD) [Range]	52 Weeks, Mean (SD) [Range]
Bone level change	IIT	0.57 (1.56) [−1.00–4.10]	0.46 (1.84) [−1.60–4.00]	0.54 (2.23) [−4.45–4.00]	1.05 (1.78) [−1.15–4.00]
	CIT	−0.45 (0.93) [−3.80–0.25]	−0.75 (1.31) [−4.35–1.80]	−0.42 (0.88) [−2.80–1.20]	−0.18 (1.26) [−3.15–2.40]
	GIT	−0.06 (0.51) [−0.70–0.80]	0.53 (0.89) [−0.10–1.80]	0.04 (0.58) [−0.50–1.20]	0.27 (0.70) [−0.35–1.65]
Mesial papillae	IIT	−0.63 (0.78) [−2.40–0.50]	−0.45 (0.92) [−1.70–0.30]	0.11 (0.84) [−1.50–1.40]	0.07 (0.99) [−1.40–1.70]
	CIT	−0.18 (1.12) [−1.70–2.70]	−0.34 (1.23) [−3.00–1.50]	−0.24 (1.33) [−3.50–2.40]	0.30 (1.38) [−2.60–3.10]
	GIT	0.20 (0.66) [−0.80–1.00]	0.50 (0.88) [−0.40–1.40]	0.30 (0.86) [−1.30–1.50]	0.61 (0.87) [−0.70–2.20]
Distal papillae	IIT*	−0.58 (1.04) [−2.60–0.90]	−0.82 (1.64) [−4.70–1.00]	−0.04 (0.95) [−1.50–1.60]	−0.38 (1.21) [−3.00–1.50]
	CIT	0.07 (0.77) [−1.00–1.90]	−0.08 (0.64) [−1.20–1.30]	0.26 (0.85) [−1.40–1.80]	0.60 (0.87) [−0.70–2.70]
	GIT	−0.08 (0.53) [−0.90–0.70]	−0.12 (0.71) [−1.10–0.50]	0.12 (0.70) [−0.90–0.90]	0.14 (0.47) [−0.30–1.20]
Midfacial level	IIT	−0.65 (0.65) [−1.90–0.40]	−0.35 (0.64) [−1.60–0.80]	−0.21 (0.62) [−1.50–1.10]	−0.12 (0.78) [−1.30–1.60]
	CIT†	−0.48 (0.50) [−1.50–0.30]	−0.92 (0.95) [−2.80–0.40]	−0.99 (1.31) [−4.80–0.90]	−1.00 (1.15) [−3.60–1.00]
	GIT	−0.58 (0.76) [−1.70–0.60]	−0.12 (0.57) [−0.60–0.70]	−0.64 (0.71) [−1.90–0.60]	−0.49 (0.82) [−2.20–0.60]

*Significant within group difference between 4 to 26 weeks and 12 to 26 weeks.
†Significant within group difference between baseline – all reassessments and 12 to 52 weeks.
IIT = immediate implant treatment ($n = 16$); CIT = conventional implant treatment ($n = 23$); GIT = grafted implant treatment ($n = 9$); negative value = hard or soft tissue loss relative to baseline (provisional crown installation); positive value = hard or soft tissue gain relative to baseline.

TABLE 6 Aesthetic Outcome at 52 Weeks Sorted per Treatment Strategy

	IIT ($n = 15$)			CIT ($n = 23$)			GIT ($n = 9$)		
	0	1	2	0	1	2	0	1	2
Mesial papilla	0	6	9	0	10	13	1	3	5
Distal papilla	2	6	7	2	7	14	1	4	4
Midfacial level	2	5	8	2	7	14	1	3	5
Midfacial contour	0	7	8	0	7	16	0	3	6
Alveolar process	1	5	9	1	10	12	1	3	5
Soft tissue color	1	5	9	1	12	10	1	3	5
Soft tissue texture	1	7	7	3	13	7	1	4	4
Pink esthetic score, mean (SD) [range]	10.33 (2.29) [6–14]			10.35 (1.58) [7–13]			10.11 (1.90) [7–14]		
Tooth form	1	6	8	4	9	10	0	4	5
Tooth volume	1	5	9	2	4	17	0	3	6
Tooth color	3	7	5	8	7	8	2	4	3
Tooth texture	0	7	8	2	6	15	1	3	5
Translucency	2	3	10	0	11	12	1	3	5
White esthetic score, mean (SD) [range]	7.20 (2.04) [3–10]			7.00 (2.37) [2–10]			7.22 (1.86) [4–10]		

IIT = immediate implant treatment; CIT = conventional implant treatment; GIT = grafted implant treatment.

aesthetic failures (PES ≤ 7 as defined by Cosyn and colleagues[23]). Hence, the majority of the cases (65%) showed an acceptable aesthetic outcome.

The mean WES after 1 year of function was 7.11 (SD 2.14, range 2–10) for all cases. Thirty-four percent of the crowns could be considered (almost) perfect (WES ≥ 9 as arbitrarily defined by Cosyn and colleagues[23]). About 21% of all crowns were aesthetic failures (PES ≤ 5 as defined by Cosyn and colleagues[23]). Hence, nearly half of the crowns (45%) showed an acceptable aesthetic outcome.

Clinical photographs and radiographs of four representative examples were included. In Figure 2E, an excellent aesthetic outcome could be achieved (IIT in a lateral incisor position with a total PES/WES of 22). Figures 3I and 4G show clinical cases with an acceptable aesthetic outcome (Figure 3I: CIT in a lateral incisor position with a total PES/WES score of 17; Figure 4G: GIT in a central incisor position with a total PES/WES score of 16). Figure 5E illustrates the case with the worst aesthetic outcome (IIT in a central incisor position with a total score of 10). Although these four examples were distinctly different from an aesthetic point of view, they were all compatible with strict implant success criteria.[35]

Patient Satisfaction

Based on the OHP-14 questionnaire, there was a statistically significant overall improvement in satisfaction and well-being between the presurgical and 1 year postoperative condition ($p < .001$) (Table 7, Figure 6, A and B). More precisely, there was a significant improvement in taste (Question 2: $p = .014$), a reduction in pain (Question 3: $p = .002$), improved eating comfort (Question 4: $p < .001$), patients were less self-conscious (Question 5: $p < .001$), felt less tensed (Question 6: $p < .001$), had more satisfactory diet (Question 7: $p = .013$), could relax easier (Question 9: $p = .005$), were less embarrassed (Question 10: $p < .001$), were less irritable (Question 11: $p = .001$), could do better their job (Question 12: $p = .011$), and life in general was more satisfying (Question 13: $p < .001$). Forty from the 47 (85%) patients had never or hardly ever problems with their teeth and mouth at 1 year follow-up.

DISCUSSION

The aim of the present study was to document the clinical, aesthetic, and patient-related outcome of immediately loaded single implants in the anterior maxilla placed in extraction sockets, healed ridges, and grafted sites. Implant survival, marginal bone adaptation,

Figure 5 Worst-case scenario of an immediate implant treatment case with PES/WES = 10. *A* and *B*, Fractured left central incisor with thick gingival biotype. *C* and *D*, Immediate implant and immediate provisionalization. *E* and *F*, One year result with Ti-Design™ abutment (Astra Tech AB) and cemented full-ceramic crown.

peri-implant mucosal responses, perceived aesthetics, and patient-related quality of life were evaluated.

The high survival rate (100%) for immediately loaded implants in a healed ridge in the current study is in line with other reports.[1,11,14,36] According to the literature, immediate loading of implants placed in extraction sockets revealed survival rates from 82 to 98%, which is comparable to what was found in this study (94%).[15,37–39] A recent meta-analysis of treatment outcomes of single implants replaced by immediate, early, and conventional loading protocols demonstrated an overall survival of 95.5% with no discernable differences between the different loading protocols.[20] Animal and human studies showed a similar degree of osseointegration for implants placed in native bone and regenerated bone using anorganic bovine bone material.[40–43] A limited number of patients were treated with the GIT procedure in this study with all implants still in function after 1 year of function.

In this study, implants were placed in extraction sockets on the basis of strict criteria excluding high-risk patients with a thin-scalloped gingival biotype and/or buccal bone defect. As a result of the latter, one-third of the sockets were considered unsuitable for IIT at the time of extraction and received socket grafting. The relative high percentage of patients in this exit group indicates that patients should be properly informed about a possible change in treatment protocol depending on the status of the buccal bone wall upon tooth removal. Unfortunately, a cone beam CT prior to tooth extraction gives limited information on the condition of the buccal bone plate.[44]

In the current study, periapical radiographs were used to measure the interproximal bone at different time points. Up till now, periapical radiographs are still the standard technique to evaluate interproximal bone

TABLE 7 Overall Mean OHIP-14 Scores for the Different Time Points Sorted per Treatment Strategy

Treatment Strategy	Before Surgery (n = 48), Mean (SD) [Range]	4 Weeks After IP (n = 46), Mean (SD) [Range]	26 Weeks After IP (n = 47), Mean (SD) [Range]	52 Weeks After IP (n = 47), Mean (SD) [Range]
IIT*	66.25 (3.86) [59–70]	67.81 (3.65) [56–70]	69.53 (0.91) [67–70]	69.67 (0.62) [68–70]
CIT†	58.78 (10.54) [38–70]	66.05 (4.44) [52–70]	64.17 (10.38) [34–70]	67.39 (6.21) [50–70]
GIT	65.78 (5.17) [57–70]	66.78 (5.58) [53–70]	66.00 (5.02) [55–70]	68.00 (4.58) [56–70]

*Significant within group difference between BFS – 26 weeks, BFS – 52 weeks, 4 to 26 weeks, and 4 to 52 weeks.
†Significant within group difference between BFS – all reassessments and 26 to 52 weeks.
IIT = immediate implant treatment; CIT = conventional implant treatment; GIT = grafted implant treatment.

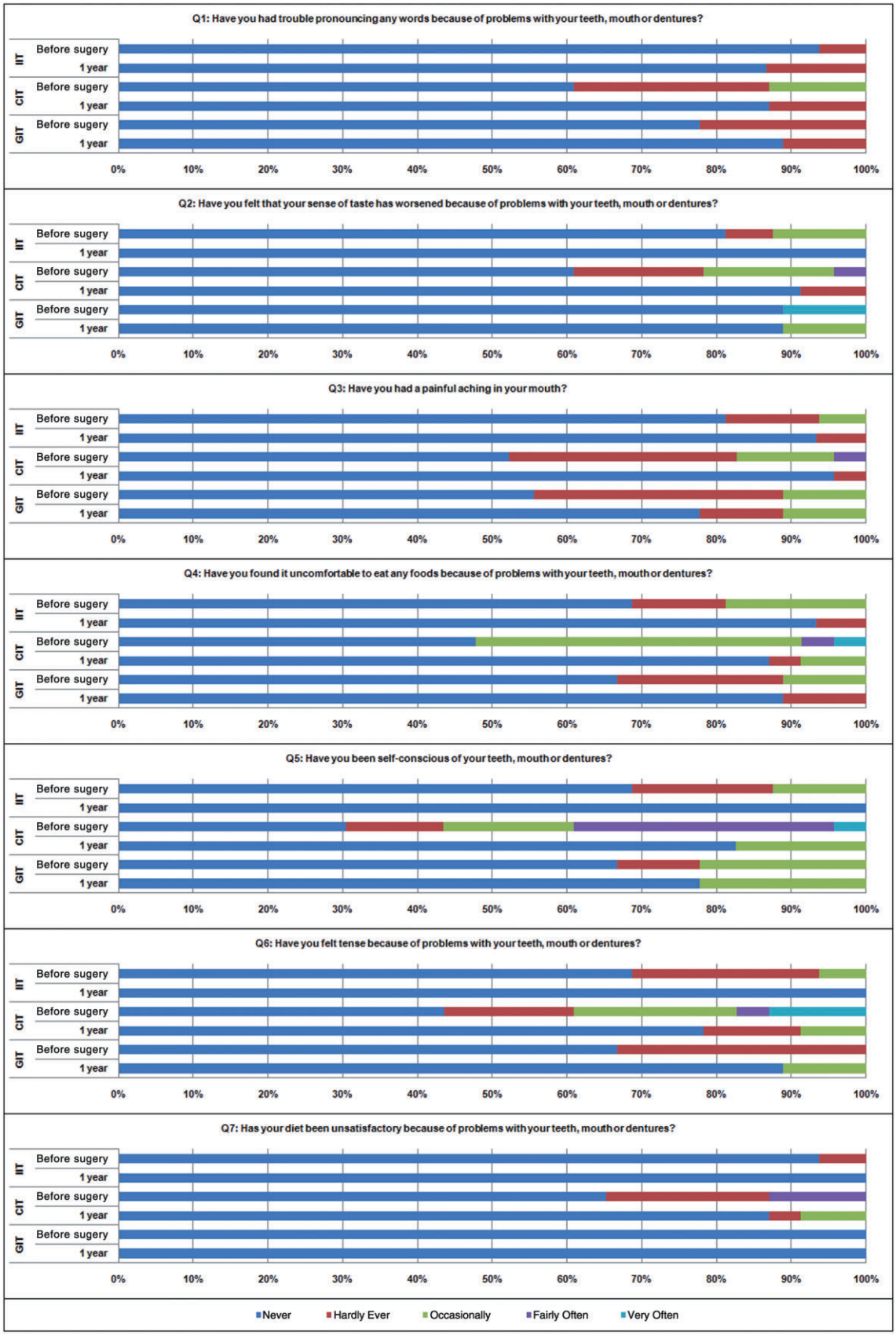

Figure 6 *A*, OHIP scores before surgery and 1 year after surgery and immediate loading sorted per treatment strategy (Q1–Q7). CIT = conventional implant treatment; GIT = grafted implant treatment; IIT = immediate implant treatment.

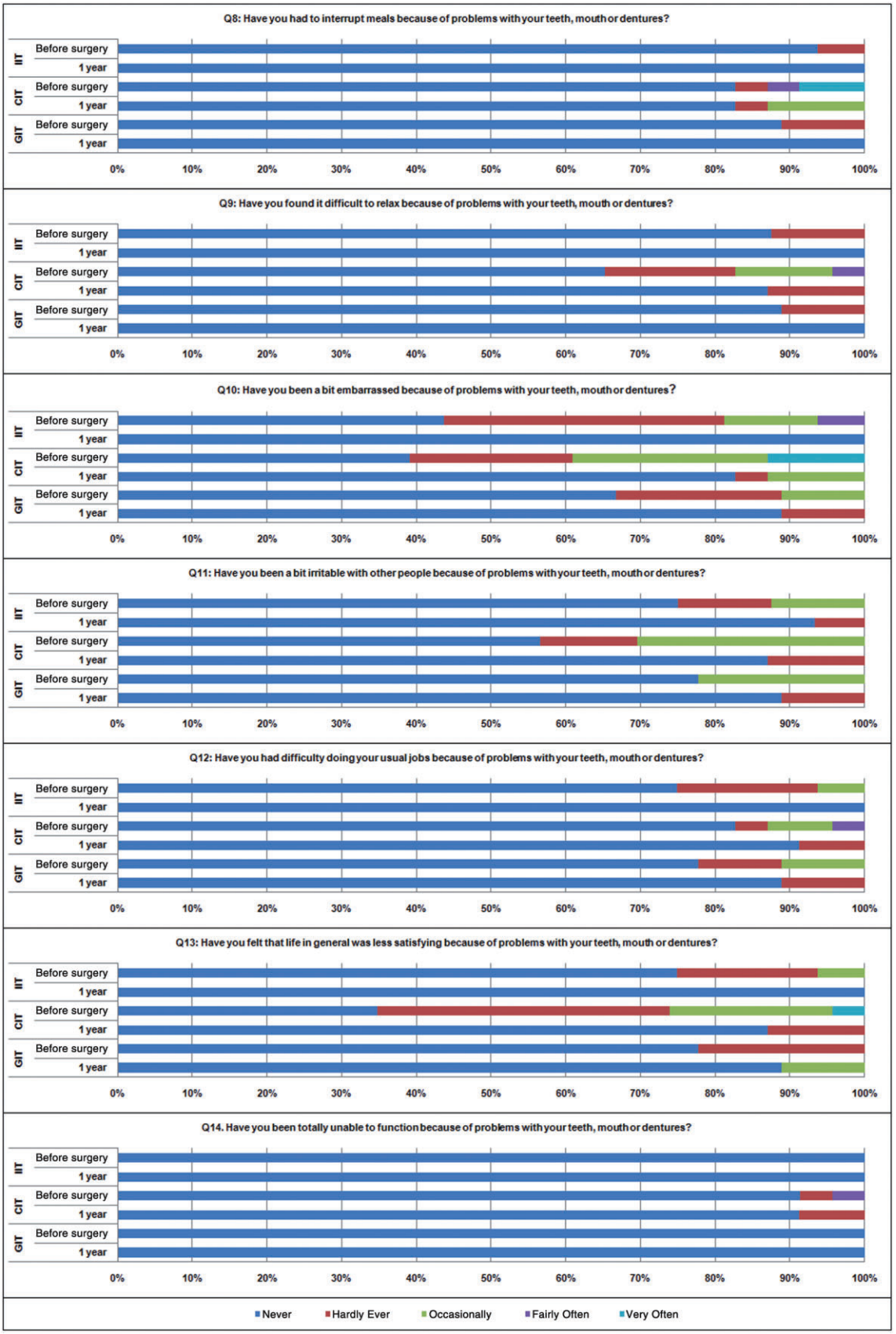

Figure 6 (*continued*). *B*, OHIP scores before surgery and 1 year after surgery and immediate loading sorted per treatment strategy (Q8–Q14). CIT = conventional implant treatment; GIT = grafted implant treatment; IIT = immediate implant treatment.

levels.[45–47] An alternative could be cone beam CT; however, it was shown that cone beam CT correlates poorly with interproximal bone level measured on periapical radiographs.[46] Hardware and/or software of cone beam CT need to be improved especially in the presence of image-distorting metallic implants, which cause beam hardening artifacts.[48,49] An important disadvantage of a cone beam CT is the higher radiation dose (≥34 microSieverts)[50,51] in comparison with a periapical radiograph (<8.3 microSieverts).[52,53]

A trend toward bone gain was found following IIT, which may be explained by the fact that the gap between the original bone and implant diminishes during healing, and the bone-to-implant contact increases in coronal direction during the healing phase. These findings can be related to a coronal bone remodeling around immediate implants and a healing pattern with new bone apposition around the neck of the implants as described in a reentry study by Covani and colleagues[54] The interproximal loss of marginal bone levels of 0.18 mm after 12 months in the CIT group is in agreement with other reports using the Astra Tech Implant System™ (Astra Tech AB) in healed ridges[55] and consistent with those obtained in an early loading study.[36]

In order to accurately evaluate soft tissue alterations, fixed reference points were used on digital color slides calibrated by model casts.[18] Complete embrasure fill was found in 60% of the cases after 1 year of follow-up. Distal papillae lost significant volume over time following IIT, which is in agreement with earlier studies on IIT.[16,56,57] In contrast, a trend towards some papilla regrowth was observed following CIT and GIT. Such papilla regrowth has been earlier described following CIT[58–62] and is initiated by the formation of a fixed contact point within 5 mm to the underlying bone.[36,63] Full papilla recovery mainly depends upon the position of the bone peak at the adjacent tooth.[58–62]

The midfacial soft tissue levels remained fairly stable over time following IIT with only 7% of the cases showing advanced recession. This finding seems to be in contrast with a recent review article by Chen and Buser.[64] However, in the present study, high-risk patients with a thin-scalloped gingival biotype and/or buccal bone defect were excluded for IIT, which could be a possible explanation for the disparity. Even though we did not use a defined socket classification system,[65] it is also likely that the current protocol's triage of patients to a grafting group avoided advanced recession in high-risk patients. In addition, immediate restoration hereby supporting the existing soft tissue architecture, could explain the limited midfacial recession we observed following IIT. In this respect, recent studies have demonstrated significantly more midfacial recession[57] and less keratinized tissue height[66] following submerged healing. On the basis of these findings, submerged healing of immediate implants should be avoided whenever possible.

Significant midfacial recession was found following CIT, which mainly developed during the early healing phase before cementation of the final crown (see Table 5). The mean shrinkage of 1 mm after 1 year of function seemed somewhat higher than what has been described for CIT.[62,67,68] We believe that the surgical procedure used in healed sites could partly explain the high risk for midfacial recession. That is, a crestal incision and use of a full-thickness flap procedure creates some excess of midfacial soft tissues following suturing around a provisional restoration. As a result of biologic width development, part of this tissue will inevitably recede, explaining excessive midfacial shrinkage following CIT especially in sites with a thin-scalloped biotype. In contrast, no such excess exists when IIT is performed resulting in more stable levels over time. The impact of the surgical technique on soft tissue response was described in a previous paper[18] with less recession following a flapless approach. A borderline association of a wide buccal bone gap (≥2 mm) with midfacial recession was also elucidated in a previous article.[18] Interestingly, no time effect was observed following GIT, which could probably be related to minimal flap elevation during implant placement and the presence of thick or medium thick gingival biotype in all cases. Another explanation could be the presence of a non-resorbable biomaterial that prevents shrinkage of the hard and soft tissues in the GIT group in contrast with the CIT group where no biomaterials were used.

Hitherto, most clinical studies focused on implant survival and success; however, it is mainly the aesthetic result that concerns patients. The overall mean PES for all cases in this study was 10.3 with an acceptable aesthetic outcome in 65% of the cases, which is comparable with other reports.[23,27] The overall mean WES for all cases of 7.1 is also in line with other studies.[23,27] When assessing the overall aesthetic treatment outcome by combining the results of the PES and WES 6.5% of the cases showed perfection and 21% could be considered aesthetic failures. This failure rate falls within the range

of what has been published;[27,69,70] however, this may be surprising because our results related to selected patients treated by well-experienced clinicians. Clearly, optimal aesthetics may be rare and failures quite prevalent following single-implant treatment even under these conditions, which is in agreement with Cosyn and colleagues[23] The failures following IIT, CIT and GIT were mainly related to pink aesthetics or white aesthetics and only a strict minority to both.

Although a massive amount of research on implant dentistry is available, limited articles reported on patient-centered outcome.[28] Of these, the majority involves fully edentulous patients who seem to profit significantly from implant rehabilitation.[71,72] Only very few single-implant studies have evaluated patient satisfaction.[29] With a significant increase in all seven domains at 1 year follow-up an overall improvement was clearly demonstrated in this study. This implies that replacing a tooth with an immediately loaded implant can substantially impact on patient's quality of life, which is in agreement with Berretin-Felix and colleagues[73] and Jokstad.[74]

An important limitation of the current study is that our results may not fully reflect current practice because no biomaterials were used in conjunction to immediate implant placement. This is mainly related to the fact that no scientific evidence was available for that at the time these patients were operated. Even today, conflicting preclinical data exist on the outcome of deproteinized bovine bone when applied in the buccal bone gap following immediate implant placement. A recent preclinical study[75] on beagle dogs demonstrated that socket grafting modified the process of hard tissue healing, provided additional amounts of hard tissue at the entrance of the previous socket and improved the level of marginal bone-to-implant contact. In contrast, an animal study[76] on mongrel dogs demonstrated that such procedure resulted in significant buccal bone loss with low osseointegration.

With respect to the limitations of the study design, we wish to emphasize this was not a randomized controlled trial making any comparison possibly biased. Even though we included consecutively treated cases, we must also acknowledge that the selection criteria for IIT and CIT were not identical. We excluded patients with a thin-scalloped biotype for IIT, and because patients in the GIT were exit patients from the IIT, a significant distortion between the groups was created. We included patients in the CIT group, which showed a limited resorption pattern with an appropriate bone volume as analyzed by a cone beam CT. In order to compare treatment modalities, especially in terms of soft tissue dynamics, one should have soft tissue data prior to tooth removal. Only then one can eliminate any preexisting disparity between groups. If not, any difference in the outcome could merely reflect a disparity in the starting point and not in the treatment itself. For all these reasons, we did not compare the outcomes of IIT, CIT, and GIT in this study.

In conclusion, this prospective study showed that single Astra Tech Osseospeed implants clinically and aesthetically perform well under immediate non-occlusal loading conditions in the premaxilla. In this context, it is of pivotal importance to stress that patients were carefully selected for IIT and GIT. In addition, all treatments were performed by experienced clinicians. Patient's quality of life improves significantly when a missing or failing tooth is replaced by an immediately non-occlusal loaded single implant in the aesthetic area.

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