Implants in Reconstructed Bone: A Comparative Study on the Outcome of Straumann® Tissue Level and Bone Level Implants Placed in Vertically Deficient Alveolar Ridges Treated by Means of Autogenous Onlay Bone Grafts

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ABSTRACT

Purpose: To evaluate: (1) the survival rate of Straumann® Tissue Level and Bone Level implants placed in atrophic edentulous jaws previously reconstructed by means of autogenous onlay bone grafts; (2) to compare peri-implant bone resorption values over time.

Materials and Methods: From 2005 to 2010, 50 patients presenting with vertical or tridimensional defects of the edentulous ridges were treated with autogenous bone grafts. Three to 7 months afterward, 192 implants were placed (Group A: 97 Tissue Level implants; Group B: 95 Bone Level implants) in the reconstructed areas. After a further waiting period of 2 to 3 months, patients were rehabilitated with implant-supported fixed prostheses. The follow-up ranged from 12 to 68 months after the start of prosthetic loading (mean: 33 months).

Results: No implants were removed (survival rate: 100%), but in Group B 13 implants (8 placed in iliac grafts, 2 placed in ramus grafts, and 3 placed in calvarial grafts) presented peri-implant bone resorption values higher than those proposed by Albrektsson and colleagues. for successful implants: the overall implant success rate was then 100% for Group A and 86.8% for Group B. No prosthetic failures were recorded, thus leading to a 100% prostheses success rate.

Conclusion: No significant differences were found between the two types of implants as far as implant survival rate is concerned, but results from this study seem to demonstrate that Tissue Level implants may present better long-term results in terms of peri-implant bone maintenance, as compared with Bone Level implants, when placed in reconstructed areas.

KEY WORDS: bone atrophy, bone graft, osseointegrated implant, platform switching

INTRODUCTION

The rehabilitation of partially and totally edentulous patients with oral implants has become a routine treatment in the last decades, with reliable long-term results.[1–12] However, unfavorable local conditions of the edentulous alveolar ridges such as bone defects due to atrophy, periodontal disease, and trauma sequelae may determine situations where bone volume is insufficient to harbor implants of adequate dimensions, and/or the proximity of anatomical structures, such as the inferior alveolar nerve, the maxillary sinus floor or the nasal floor, renders the placement of implants impossible. Moreover, vertical, horizontal or tridimensional defects can alter the intermaxillary relationships, with increased interarch distance and/or horizontal discrepancies. For cases in which the use of short (<8 mm) implants is not indicated or impossible due to the lack of bone, different surgical methods have been proposed to treat bone deficiency, such as guided bone regeneration techniques,[13–20]

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bone reconstruction by means of autogenous onlay bone grafts,[12,21–47] bone formation induced by distraction osteogenesis,[48–56] and bone reconstruction by means of revascularized free flaps.[57–63] Among these surgical techniques, bone reconstruction with onlay bone grafts is the most versatile, as it can be used to treat the vast majority of defects irrespective of variables such as type of atrophy and extent of the defect, and clinical results are favorable and stable in time either for the reconstructed bone and for implants placed in the reconstructed areas, with implant survival rates ranging from 90 to 100% for rough surface implants (mean: 94.2%).[64]

One of the critical factors influencing long-term implant survival and success rate is the maintenance of peri-implant bone, measured in terms of vertical peri-implant bone resorption. This factor is influenced by aspects such as the type of bone used for the reconstruction, the extent of the reconstruction, the presence or absence of peri-implant infection, the implant macro and micro morphology, and the type of connection between the implant and the prosthetic suprastructure. As far as this last factor is concerned, a series of studies seem to demonstrate that moving the connection between implant and abutment from the edge of the implant shoulder toward the center of the implant (the platform-switching concept) may reduce the risk of peri-implant bone resorption.[65–73] In fact, the displacement of the microgap between implant and abutment from the bone-to-implant interface toward the inner part of the implant shoulder should move away bacteria from the peri-implant bone and improve the biological width. These aspects seem to lead to a reduction of peri-implant bone resorption, as reported in a recent systematic review of the literature.[72] Yet, while several articles on the role of platform switching on peri-implant bone maintenance are present in the literature for implants placed in native bone,[72–76] there is a lack of: (1) publications reporting data on implants with this characteristic placed in reconstructed bone; and (2) comparative studies between platform-switching and non-platform-switching implants placed in atrophic jaws reconstructed by means of autogenous onlay bone grafts harvested from different donor sites.

The aim of this retrospective study is therefore to evaluate and compare: (1) the survival rate of Tissue Level (characterized by a trans-mucosal design) and Bone Level (characterized by a platform-switching design) implants placed in alveolar ridges reconstructed by means of autogenous onlay bone grafts; (2) the peri-implant bone resorption values around the two types of implants over time.

MATERIALS AND METHODS

From 2005 to 2010, 50 patients (16 male patients, 34 female patients) with ages ranging from 19 to 69 years (mean: 49.5) were treated, and clinical outcomes were recorded and analyzed.

The inclusion criterion for this study was the presence in the mandible and/or maxilla of an edentulous area with a degree of vertical bone atrophy that: (1) rendered the placement of implant of at least 6 mm of length impossible for anatomical and/or functional reasons; (2) produced an increase in interarch distance that, if not treated, would render prosthetic rehabilitation inadequate from a functional and/or esthetic point of view, even if bone volume was sufficient to harbor implants.

Exclusion criteria included the presence of one or more of the following conditions: (1) severe kidney and/or liver disease; (2) congenital or acquired immunodeficiency; (3) ongoing antiblastic chemotherapy at the time of first examination; (4) sequelae of radiotherapy in the head and neck area; (5) non-compensated diabetes; (6) ongoing biphosphonate therapy with oral or parenteral administration; (7) active periodontal disease at the time of first examination (in this case, patients underwent etiologic therapy, education and motivation in domestic oral hygiene, and were reevaluated for surgical treatment); (8) oral mucosae diseases, such as lichen; (9) poor oral hygiene; (10) tobacco abuse (>20 cigarettes per day) or alcohol abuse; and (11) non-compliant patients.

All the selected patients presented with severe vertical or tridimensional defects of the alveolar ridges, and the deficient areas were treated by means of autogenous onlay bone grafts harvested from intraoral or extraoral donor sites (Table 1 for details).

After a waiting period of 3 to 7 months to allow integration of the grafts, 192 implants (Group A: 97 Tissue Level implants; and Group B: 95 Bone Level implants) were placed, and osseointegration was obtained with a submerged healing protocol. A further waiting period of 2 to 3 months was allowed to obtain osseointegration, and prosthetic rehabilitation was then carried out.

TABLE 1A Patients' Demographic and Clinical Data (Group A – Tissue Level Implants)

N°	Sex	Age	Site of Atrophy	Date of Reconstruction	Type of Reconstruction	Donor Site	Recipient Site Complications	Date Implant Placement
1	F	56	Max (p)	07-2008	Vert + hor	Ramus	—	11-2008
2	F	63	Mand (p)	05-2007	Vert + hor	Ramus	—	10-2007
3	F	39	Mand (p)	05-2009	Vert + hor	Calvarium	50% Vertical graft resorption	10-2009
4	F	50	Mand (p)	07-2009	Vert + hor	Calvarium	—	12-2000
5	F	69	Max (p)	04-2007	Vert + hor	Ilium	—	07-2007
6	M	59	Max (p)	07-2005	Vert + hor	Ilium	—	12-2005
7	F	61	Max (t) mand (p)	03-2006	Vert + hor	Calvarium	—	07-2006
8	M	60	Max (p)	05-2008	Vert + hor	Ilium	—	09-2008
9	F	67	Max (t)	09-2006	Vert + hor	Calvarium	—	02-2007
10	M	51	Max (p) mand (p)	09-2008	Vert + hor	Ilium	—	01-2009
11	F	59	Mand (p)	02-2009	Vert + hor	Calvarium	—	09-2009
12	M	27	Max (p)	01-2007	Vert + hor	Calvarium	—	07-2007
13	F	57	Max (p)	04-2005	Vert + hor	Calvarium	—	10-2005
14	M	63	Max (p)	03-2005	Vert + hor	Ilium	—	06-2005
15	M	54	Max (t) mand (p)	02-2008	Vert + hor	Ilium	—	07-2008
16	M	19	Max (p)	01-2006	Vert + hor	Ramus	—	07-2006
17	F	22	Max (p)	03-2006	Vert + hor	Ramus	—	09-2006
18	F	29	Max (p)	02-2005	Vert + hor	Ramus	—	06-2005
19	F	64	Mand (p)	01-2005	Vert + hor	Calvarium	—	06-2005
20	F	43	Mand (p)	06-2008	Vert	Ramus	—	10-2008
21	F	21	Max (p)	04-2006	Vert + hor	Ramus	—	10-2006
22	F	57	Mand (p)	06-2006	Vert + hor	Ramus	—	11-2006
23	F	56	Mand (p)	05-2005	Vert + hor	Ramus	—	09-2006
24	F	43	Max (p)	03-2005	Vert + hor	Ramus	—	07-2005
25	F	60	Mand (p)	03-2005	Vert	Calvarium	—	09-2005

TABLE 1B Patients' Demographic and Clinical Data (Group B – Bone Level Implants)

N°	Sex	Age	Site of Atrophy	Date of Reconstruction	Type of Reconstruction	Donor Site	Recipient Site Complications	Date Implant Placement
1	F	57	Mand (p)	01-2007	Vert + hor	Calvarium	—	07-2007
2	F	56	Mand (p)	05-2007	Vert + hor	Ramus	—	10-2007
3	F	55	Max (p)	06-2007	Vert + hor	Ramus	—	11-2007
4	F	40	Max (p)	10-2007	Vert	Ramus	—	02-2008
5	M	53	Mand (p)	01-2008	Vert + hor	Ramus	—	06-2008
6	M	52	Max (p)	04-2008	Vert + hor	Ramus	—	09-2008
7	F	54	Max (t)	05-2008	Vert + hor	Calvarium	Dehiscence	10-2008
8	M	29	Mand (p)	09-2008	Vert	Ramus	—	02-2009
9	F	41	Max (t)	10-2008	Vert	Calvarium	—	05-2009
10	M	54	Mand (p)	10-2008	Vert	Ramus	—	03-2009
11	M	41	Max (p)	06-2009	Vert + hor	Ramus	—	11-2009
12	F	48	Max (p)	06-2009	Vert + hor	Ramus	—	11-2009
13	F	69	Max (p)	07-2009	Vert + hor	Calvarium	—	12-2009
14	F	68	Mand (p)	07-2009	Vert	Calvarium	—	12-2009
15	M	18	Max (p)	07-2009	Vert + hor	Ramus	—	12-2009
16	F	36	Max (p)	09-2009	Vert + hor	Calvarium	—	01-2010
17	F	66	Mand (p)	09-2009	Vert	Calvarium	—	01-2010
18	F	47	Mand (p)	10-2009	Vert + hor	Ramus	—	01-2010
19	F	33	Mand (p) max (p)	09-2007	Vert + hor	Ilium	—	01-2008
20	M	57	Mand (p)	02-2009	Vert + hor	Ilium	—	06-2009
21	F	55	Max (p)	01-2008	Vert + hor	Ilium	—	05-2008
22	F	25	Max (p)	06-2009	Vert + hor	Ilium	Dehiscence	11-2009
23	M	55	Mand (p) max (p)	07-2007	Vert + hor	Ilium	—	09-2007
24	M	68	Max (p)	01-2008	Vert + hor	Ilium	—	05-2008
25	F	52	Max (p)	04-2008	Vert + hor	Ilium	—	09-2008

Hor, horizontal; mand, mandible; max, maxilla; (p), partially edentulous; (t), totally edentulous; vert, vertical.

Documentation for all clinical cases included: (1) intraoral photographs of the initial clinical situation; (2) panoramic radiograph (and a complete series of periapical radiographs for partially edentulous patients); (3) impressions and plaster casts with diagnostic wax-up for the fabrication of radiographic/surgical stents with radio-opaque markers; (4) preoperative computed tomography scans treated with a dedicated software to evaluate the morphology of the alveolar ridges in the edentulous areas, to be taken with the radiographic stent in place.

All patients underwent a professional oral hygiene treatment from 1 to 2 weeks before the date planned for surgery, even if no signs of periodontal disease were present.

Besides normal oral hygiene maneuver, patients were asked to start chlorhexidine mouth rinses (0.2% concentration three times per day) 2 days before the date scheduled for the reconstructive surgery, and an antibiotic prophylaxis consisting of oral administration (15 patients) of amoxicillin and clavulanate (1 gram tablets, 2 tablets 1 hour prior to surgery and 1 tablet 6 hours later). Thirty-five patients, treated under general anesthesia, were given the same antibiotic via intravenous administration during anesthesia induction.

All surgical procedures (bone reconstructions and implant placement) were performed by the same surgical team.

Reconstructive Procedure

For the reconstruction in the edentulous areas, autogenous bone blocks were harvested from intraoral (ramus) or extraoral (ilium, calvarium) donor sites. The choice between intraoral or extraoral donor sites was mainly dictated by the extent of the defect, and consequently, by the quantity of bone needed to recreate an adequate bone volume in the deficient area. In cases of partial edentulism and limited defects, an intraoral site was chosen (mandibular ramus: 21 patients), while in case of extended defects in partially and totally edentulous patients an extraoral donor site was the choice (ilium: 13 patients; calvarium: 16 patients). The extraoral donor site of first choice was always the calvarium, due to the quantity and quality of available bone: in fact, parietal bone is highly corticalized and dense, and is therefore less prone to resorption. The ilium was chosen as a donor site for patients that refused calvarial harvesting for personal reasons. In 11 patients, presenting with severe atrophy of the maxilla in conjunction with maxillary sinus expansion, sinus grafting procedures with a lateral approach (unilateral or bilateral) were performed, by mixing in a 50% proportion iliac cancellous bone and biomaterials (Bio-Oss®, Geistlich Biomaterials, Wolhusen, Switzerland), in association with the crestal reconstruction.

The choice between the different types of anesthesia was made considering the duration and the complexity of the procedure, the extent of the defect to be reconstructed, the donor site chosen for bone harvesting, and the patient's compliance. All patients for whom bone harvesting from extraoral sites was chosen (29 patients) were treated under general anesthesia; the same choice was made for six patients who underwent bone harvesting from the mandibular ramus, due to the estimated length and complexity of the surgical procedure and/or the patient's requests. The remaining 15 patients were treated under local anesthesia or local anesthesia in association with intravenous sedation.

Once harvesting of the bone blocks was completed, the reconstructive phase started with the elevation of a full-thickness flap to expose the deficient edentulous area. The blocks were then modeled to obtain a precise adaptation to the recipient site and were then fixed to the basal bone by means of titanium microscrews. All the gaps between the bone blocks were filled with autogenous particulate bone. A layer of biomaterial characterized by a low resorption rate (Bio-Oss®) was laid over the graft, and the reconstructed site was covered with collagen membranes (Bio-Gide®, Geistlich Biomaterials). In cases where horizontal bone loss was associated with the vertical atrophy (42 patients), correction of both the vertical and horizontal aspect of the defect were treated in the same surgical session (see Table 1 for details). After the completion of the reconstructive phase, periosteal incisions were performed to allow a tension-free closure of the surgical flaps.

Antibiotic therapy via oral administration was prescribed to all patients for 6 days after the reconstructive procedure (amoxicilline associated with clavulanate, 1 gram tablets – 1 tablet every 8 hours for 4 days, and 1 tablet every 12 hours for the following 3 days). Postoperative instructions included liquid/soft diet and thorough oral hygiene with toothbrush (if residual dentition was present) and chlorhexidine (0.2%) mouthwashes until suture removal, which was performed 10 to 15 days after the reconstruction.

Patients treated under local anesthesia were discharged in 1 hour after the end of surgery, while patients treated under general anesthesia for intraoral harvesting were discharged within 8 hours afterward. Patients treated under general anesthesia for extraoral harvesting (ilium, calvarium) were discharged between 24 and 72 hours after the end of the surgical session.

During the postoperative period, totally edentulous patients were not allowed to wear prostheses that could stress the reconstructed ridges for a minimum of 6 weeks. In the following period, until implant placement, prostheses relined with soft materials were allowed for cosmetic use, with the prohibition to use them for chewing hard food. Partially edentulous patients were provisionally rehabilitated with fixed partial prostheses (e.g., Maryland bridges), provided that these had no contact with the reconstructed areas.

Surgical Procedure – Implant Phase

Three to 7 months after the reconstruction (4 to 5 for ramus grafts; 5 to 7 for calvarial grafts; 3 to 5 for iliac grafts), the second surgical session was scheduled for implant placement. Thirty-eight patients were treated under local anesthesia, five patients were treated under local anesthesia associated with intravenous sedation, and seven patients were treated under general anesthesia. The choice between the different types of anesthetic protocols was made according to the extension of the area to be rehabilitated, the number of implants to be placed, the duration of the surgical session, and the patients' compliance.

The intervention started with the elevation of a full-thickness flap along the same incision line used for the reconstructive procedure, and the removal of the microscrews used to fix the grafts was then carried out. When a screw was not interfering with implant positioning and was difficult to reach, the screw was left in place to avoid any unnecessary graft exposure.

A total of 192 implants (Straumann GmbH, Basel, Switzerland) were placed (Group A: 97 Tissue Level implants; Group B: 95 Bone Level implants). Implant dimensions were chosen according to prosthetic indications and to the bone volume obtained with the reconstruction in the single implant sites. Implants positions were chosen according to the prosthetic planning reproduced by the radiographic/surgical templates based on the ideal wax-up of the missing dentition. After implant placement, cover screws were placed on the implants to achieve a submerged healing, sutures were applied and patients were discharged with the same postoperative instructions given for the reconstructive phase. Details regarding the implant phase are reported in Table 2.

Prosthetic Phase

Two to 3 months after placement, implants were uncovered and healing abutments connected. Provisional prostheses were fabricated and delivered and, once adequate conditioning of the soft tissues was obtained, they were replaced by the definitive prostheses (see Table 2 for details). Patients were then scheduled for periodical clinical and radiographic controls.

Parameters Evaluated in the Follow-Up Period

To obtain data on bone resorption and implant performance in reconstructed bone, the following parameters were evaluated: (1) bone resorption before implant placement; (2) peri-implant bone resorption; (3) implant survival; (4) implant success rate; and (5) implant-related complications.

Periapical radiographs were taken immediately after implant placement, and annually thereafter: peri-implant bone resorption was evaluated by two independent investigators on these radiographs by measuring the distance between the implant shoulder and the most coronal point of bone to implant contact mesial and distal to each implant. Measurements were performed using a dedicated software (ImageJ® 1.38 v, National Institutes of Health, Bethesda, MD, USA), after digitalization of all radiographs with a Nikon D70S camera (Nikon Corp., Tokyo, Japan), and were rounded to the nearest half millimeter. For each implant, a mathematical mean between the value measured on the mesial and distal aspects of the implant shoulder was calculated to obtain a mean resorption value.

Implant survival and implant-related complications were registered and evaluated. The following conditions were considered as implant-related complications: (1) peri-implant infection; (2) chronic pain associated with the implant; (3) paresthesia/disesthesia; (4) peri-implant bone resorption exceeding one-third of the implant length; (5) implant mobility; (6) implant removal; and (7) implant fracture.

Successful implants are characterized by the following criteria: (1) absence of persistent pain or dysesthesia; (2) absence of perimplant infection with suppuration; (3) absence of mobility; (4) absence of continuous

TABLE 2A Patients' Demographic and Clinical Data (Group A – Tissue Level Implants)

N°	Sex	Age	Site of Atrophy	Date Implant Placement	Implants (*n*°/Dimensions)	Date of Loading	Implant Complications	Type of Prosthesis	Follow-Up
1	F	56	Max (p)	11-2008	2 (4.1 × 10)	02-2009	—	FPP	24
2	F	63	Mand (p)	10-2007	3 (3.3 × 10)	02-2008	—	FPP	36
3	F	39	Mand (p)	10-2009	2 (4.1 × 6)	02-2010	—	FPP	12
4	F	50	Mand (p)	12-2000	2 (4.1 × 6)	03-2010	—	FPP	12
5	F	69	Max (p)	07-2007	4 (4.1 × 10)	11-2007	—	FPP	30
6	M	59	Max (p)	12-2005	2 (4.1 × 12)	04-2006	—	FPP	60
7	F	61	Max (t) mand (p)	07-2006	5 (4.1 × 12)/7 (4.1 × 10)	11-2006	—	FCP/FPP	50
8	M	60	Max (p)	09-2008	6 (4.1 × 10)	12-2008	—	FPP	30
9	F	67	Max (t)	02-2007	6 (3.3 × 12)	06-2007	—	FCP	48
10	M	51	Max (p) mand (p)	01-2009	7 (4.1 × 10)/1 (4.1 × 8)	04-2009	—	FPP	24
11	F	59	Mand (p)	09-2009	2 (4.1 × 10)/1 (4.1 × 8)	12-2009	—	FPP	18
12	M	27	Max (p)	07-2007	3 (3.3 × 12)	11-2007	—	FPP	40
13	F	57	Max (p)	10-2005	5 (4.1 × 10)	01-2006	—	FPP	64
14	M	63	Max (p)	06-2005	2 (4.1 × 10)/3 (4.8 × 10)	10-2005	—	FPP	68
15	M	54	Max (t) mand (p)	07-2008	3 (3.3 × 12)/7 (4.1 × 10)	11-2008	—	FCP/FPP	30
16	M	19	Max (p)	07-2006	2 (4.1 × 12)	10-2006	—	FPP	50
17	F	22	Max (p)	09-2006	2 (4.1 × 12)	12-2006	—	FPP	54
18	F	29	Max (p)	06-2005	2 (3.3 × 12)	09-2005	—	FPP	68
19	F	64	Mand (p)	06-2005	3 (4.1 × 12)	10-2005	—	FPP	66
20	F	43	Mand (p)	10-2008	2 (4.1 × 10)	12-2008	—	FPP	30
21	F	21	Max (p)	10-2006	2 (3.3 × 12)	12-2006	—	FPP	52
22	F	57	Mand (p)	11-2006	2 (4.1 × 8)/1 (3.3 × 10)	03-2007	—	FPP	48
23	F	56	Mand (p)	09-2006	1 (4.1 × 10)/1 (4.1 × 8)	01-2006	—	FPP	60
24	F	43	Max (p)	07-2005	2 (3.3 × 12)	11-2005	—	FPP	66
25	F	60	Mand (p)	09-2005	4 (4.1 × 8)	12-2005	—	FPP	60

TABLE 2B Patients' Demographic and Clinical Data (Group B – Bone Level Implants)

N°	Sex	Age	Site of Atrophy	Date Implant Placement	Implants (*n*°/Dimensions)	Date of Loading	Implant Complications	Type of Prosthesis	Follow-Up
1	F	57	Mand (p)	07-2007	(3) 4.1 × 10	10-2007	—	FPP	36
2	F	56	Mand (p)	10-2007	(3) 4.1 × 10	01-2008	—	FPP	36
3	F	55	Max (p)	11-2007	(2) 4.1 × 10	02-2008	—	FPP	36
4	F	40	Max (p)	02-2008	(1) 3.3 × 12/(2) 4.1 × 12	05-2008	—	FPP	30
5	M	53	Mand (p)	06-2008	(2) 4.1 × 10	09-2008	—	FPP	24
6	M	52	Max (p)	09-2008	(5) 4.1 × 10	01-2009	—	FPP	24
7	F	54	Max (t)	10-2008	(1) 4.1 × 10/(5) 4.1 × 12	01-2009	—	FCP	24
8	M	29	Mand (p)	02-2009	(2) 4.1 × 10	05-2009	—	FPP	18
9	F	41	Max (t)	05-2009	(3) 4.1 × 10/(5) 3.3 × 10	09-2009	Perimplantitis (2 imp)	FCP	12
10	M	54	Mand (p)	03-2009	(3) 4.1 × 10	06-2009	—	FPP	18
11	M	41	Max (p)	11-2009	(2) 4.1 × 10	02-2010	—	FPP	12
12	F	48	Max (p)	11-2009	(2) 4.1 × 10	02-2010	—	FPP	12
13	F	69	Max (p)	12-2009	(3) 4.1 × 10	02-2010	—	FPP	12
14	F	68	Mand (p)	12-2009	(4) 4.1 × 10	02-2010	—	FPP	12
15	M	18	Max (p)	12-2009	(2) 4.1 × 10	02-2010	—	FPP	12
16	F	36	Max (p)	01-2010	(2) 3.3 × 12	04-2010	—	FPP	12
17	F	66	Mand (p)	01-2010	(4) 3.3 × 12/(1) 4.1 × 10	04-2010	—	FPP	12
18	F	47	Mand (p)	01-2010	(3) 4.1 × 10	04-2010	—	FPP	12
19	F	33	Mand (p) max (p)	01-2008	7 (4.1 × 10)/2 (4.1 × 8)	04-2008	—	FPP	36
20	M	57	Mand (p)	06-2009	2 (4.1 × 10)/2 (4.1 × 8)	09-2009	Sth (2 impl) – perimplantitis (2 imp)	FPP	20
21	F	55	Max (p)	05-2008	6 (4.1 × 10)	09-2008	—	FPP	30
22	F	25	Max (p)	11-2009	2 (3.3 × 12)	02-2010	—	FPP	12
23	M	55	Mand (p) max (p)	09-2007	7 (4.1 × 10)	12-2007	Sth/perimplantitis (2 imp)	FPP	40
24	M	68	Max (p)	05-2008	3 (4.1 × 10)	09-2008	—	FPP	30
25	F	52	Max (p)	09-2008	2 (4.1 × 10)	12-2008	Sth (1 imp)	FPP	30

FCP, fixed complete prosthesis; FPP, fixed partial prosthesis; imp, implant; mand, mandible; max, maxilla; (p), partially edentulous; sth, soft tissues hyperplasia; (t), totally edentulous.

peri-implant radiolucency; and (5) peri-implant bone resorption less than 1.5 mm in the first year of function and less than 0.2 mm in the following years.[1]

All data were analyzed using descriptive statistical methods.

RESULTS

Postoperative recovery after the reconstructive procedure was uneventful in the majority of cases. Only in 3 out of 50 patients (one patient in Group A, two patients in Group B) localized dehiscences of the soft tissues in the reconstructed areas occurred. The dehiscences were treated with thorough curettage of the exposed bone and oral antiseptics support to promote secondary intention healing, which occurred in all cases between 6 and 11 days after the treatment. In two cases the complication caused only a small area of graft resorption, while in one case a partial graft loss (50% of the reconstructed volume) occurred. However, this complication did not prevent from completing the original treatment plan, as far as implants and prosthetics were concerned.

Five patients reported inferior lip/chin paresthesia for a duration of 1 to 12 weeks after ramus harvesting and/or lateral-posterior mandibular reconstruction. Complete functional recovery was obtained in all cases.

All patients treated with bone reconstructions underwent the second surgical phase of implant placement.

A total of 192 implants were placed in the reconstructed areas: all implants achieved successful osseointegration and were prosthetically loaded.

The follow-up after the start of prosthetic loading ranged from a minimum of 12 to a maximum of 68 months, with a mean follow-up of 33 months (see Table 2 for details).

None of the implants was removed due to untreatable infection, mobility, or fracture, thus leading to an overall implant survival rate of 100%.

In three patients, an inflammatory response that led to the formation of hyperplastic soft tissue surrounding the trans-mucosal portion of five implants was observed 12 to 24 months after completion of the prosthetic rehabilitation. In two out of three patients soft tissue hyperplasia was associated with perimplantitis.

In one patient, perimplantitis involving two implants without growth of hyperplastic soft tissue occurred 8 months after the start of prosthetic loading.

The treatment protocol for perimplantitis comprehended the elevation of a surgical flap and peri-implant curettage consisting of the smoothening of the implant surface by means of diamond burs and rubber tips mounted on contra-angle handpieces under irrigation with sterile saline solution, and suture of the surgical flap.

The treatment protocol for hyperplastic soft tissue growth comprehended the elevation of a surgical flap, the excision of the hyperplastic tissue and peri-implant curettage as described above, in association with keratinized mucosa grafts harvested from the palatal vault. Successful outcome of the procedure was obtained in all cases without any relapse, although a peri-implant bone loss ranging from 0.5 to 4.5 mm was observed (Tables 3B and 4B).

The overall implant complication rate was 0% for Group A, and 5.4% for Group B.

However, it is worth noting that all implant-related complications (peri-implant soft tissue reaction and relevant peri-implant bone resorption) occurred in Group B patients reconstructed with iliac grafts, while no adverse events occurred in Group A patients and in Group B patients treated with ramus or calvarial grafts. Therefore, the implant complication rate according to type of graft was 0% in case of ramus and calvarial grafts for both Group A and Group B, while in case of iliac grafts it was 0% for Group A and 15.2% for Group B, respectively.

The mean peri-implant bone resorption for Group A patients was 0.23 mm (range: 0–1 mm; SD: 0.30) for implants placed in areas reconstructed with ramus grafts, 0.36 mm (range: 0–1 mm; SD: 0.39) for implants placed in iliac grafts, and 0.21 mm (range: 0–1 mm; SD: 0.37) for implants placed in calvarial grafts.

The mean peri-implant bone resorption for Group B patients was 0.48 mm (range: 0–1.25 mm; SD: 0.42) for implants placed in areas reconstructed with ramus grafts, 1.34 mm (range: 0–4.5 mm; SD: 1.33) for implants placed in iliac grafts, and 0.35 mm (range: 0–1 mm; SD: 0.52) for implants placed in calvarial grafts.

Peri-implant bone resorption values in the two groups were compared using a two-tail, unpaired *t*-test: result of the test showed a p value $< .0001$, which by conventional criteria is considered extremely statistically significant. Peri-implant bone resorption values were

TABLE 3A Data on Peri-Implant Bone Resorption (Group A – Tissue Level Implants)

Peri-Implant Bone Resorption Frequency Distribution	Calvarium	Mandibular Ramus	Ilium
	40 Implants	22 Implants	35 Implants
0 mm	29 (72.5%)	13 (59%)	17 (48.5%)
<0.9 mm	5 (12.5%)	8 (36.5%)	11 (31.5%)
1–1.9 mm	6 (15%)	1 (4.5%)	7 (20%)
2–2.9 mm	0	0	0
3–3.9 mm	0	0	0
>4 mm	0	0	0

Peri-Implant Bone Resorption	Calvarium	Mandibular Ramus	Ilium
Mean (SD)	0.21 (0.37)	0.23 (0.30)	0.36 (0.39)
Median	0.0	0.0	0.5
1st quartile	0.0	0.0	0.0
3rd quartile	0.5	0.5	0.5
Minimum	0.0	0.0	0.0
Maximum	1.0	1.0	1.0

also analyzed according to type of graft (calvarium, ramus, and ilium) using two-tail, unpaired *t*-tests: results obtained showed no statistically significant differences between the two groups for implants placed in calvarial grafts, statistically significant differences for implants placed in ramus grafts, and extremely significant statistical differences for implants placed in iliac grafts. Details of the *t*-tests results are presented in Table 5.

Statistical data (mean, median, frequency distribution, and interquartile ranges) on peri-implant bone resorption are reported in Table 3.

As far as implant success rates according to type of graft are concerned, results showed in Group A a success rate of 100% irrespective of the type of bone used for the reconstruction, while in Group B the success rate was 93.5% for implants placed in ramus grafts, 90.3% for implants placed in calvarial grafts, and 76.4% for

TABLE 3B Data on Peri-Implant Bone Resorption (Group B – Bone Level Implants)

Peri-Implant Bone Resorption Frequency Distribution	Calvarium	Mandibular Ramus	Ilium
	31 Implants	31 Implants	33 Implants
0 mm	17 (55%)	11 (35%)	5 (15.2%)
<0.9 mm	8 (26%)	12 (39%)	8 (24.3%)
1–1.9 mm	5 (16%)	8 (26%)	12 (36.3%)
2–2.9 mm	1 (3%)	0	2 (6%)
3–3.9 mm	0	0	4 (12.2%)
>4 mm	0	0	2 (6%)

Peri-Implant Bone Resorption	Calvarium	Mandibular Ramus	Ilium
Mean (SD)	0.35 (0.52)	0.48 (0.42)	1.34 (1.33)
Median	0.0	0.5	1.0
1st quartile	0.0	0.0	0.25
3rd quartile	0.5	0.88	2.13
Minimum	0.0	0.0	0.0
Maximum	1.0	1.25	4.5

TABLE 4A Peri-Implant Bone Resorption (PIBR) and Implant Survival Rate – Lifetable Analysis (Group A – Tissue Level Implants)

Iliac Grafts	*N*° Impl at Risk	*N*° Removed Impl	*N*° Failing Impl	Mean PIBR (Range)	Survival Rate (%)	Success Rate (%)
Plc – load	35	0	0	0–1 mm	100	100
Load – 1 year	35	0	0		100	100
1 year–2 year	35	0	0		100	100
2–3 years	35	0	0		100	100
2–3 years	7	0	0		100	100
3–4 years	7	0	0		100	100
4–5 years	7	0	0		100	100
Ramus Grafts	***N*° Impl at Risk**	***N*° Removed Impl**	***N*° Failing Impl**	**Mean PIBR (Range)**	**Survival Rate (%)**	**Success Rate (%)**
Plc – load	22	0	0	0–1 mm	100	100
Load – 1 year	22	0	0		100	100
1 year–2 years	22	0	0		100	100
2–3 years	22	0	0		100	100
3–4 years	18	0	0		100	100
4–5 years	15	0	0		100	100
5–6 years	6	0	0		100	100
Calvarial Grafts	***N*° Impl at Risk**	***N*° Removed Impl**	***N*° Failing Impl**	**Mean PIBR (Range)**	**Survival Rate (%)**	**Success Rate (%)**
Plc – load	40	0	0	0–1 mm	100	100
Load – 1 year	40	0	0		100	100
1 year–2 years	40	0	0		100	100
2–3 years	33	0	0		100	100
3–4 years	33	0	0		100	100
4–5 years	30	0	0		100	100
5–6 years	12	0	0		100	100

implants placed in iliac grafts. Overall implant success rates in Group A and Group B were 100% and 86.8%, respectively. Data concerning the success rates of implants were calculated according to the standard actuarial method (details are reported in Table 4).

No prosthetic complications were reported during the observation period in neither of the two groups, thus leading to a 100% prosthetic success rate for both Group A and Group B (see Tables 3 and 4).

Three clinical cases are presented in Figures 1–3.

DISCUSSION

Among all the reconstructive techniques used in case of severe atrophy of the edentulous ridges to allow the placement of implants of adequate dimensions and in proper position from a prosthetic point of view, autogenous onlay bone grafts represent the most documented procedure in the literature, in terms of patients' sample and length of the follow-up period. Long-term results of implants placed in the reconstructed jaws, as well as bone volume maintenance over time, are satisfactory, with a mean implant survival rate around 90%, as reported in recently published literature reviews on this subject.[64,77]

In some cases, however, although implants remain integrated and stable, a variable share of vertical resorption of the reconstructed bone has been observed. The most significant factor influencing resorption of the grafted bone seems to be the type of graft: the presence and prevalence of cancellous bone, as for iliac grafts, determines resorption values higher than those reported in cases where only cortical bone is used, such as ramus or calvarial grafts.[64,77]

TABLE 4B Peri-Implant Bone Resorption (PIBR) and Implant Survival Rate – Lifetable Analysis (Group B – Bone Level Implants)

Iliac Grafts	*N*° Impl at Risk	*N*° Removed Impl	*N*° Failing Impl	Mean PIBR (Range)	Survival Rate (%)	Success Rate (%)
Plc – load	33	0	0	0–4.5 mm	100	100
Load – 1 year	33	0	7		100	78.79
1 year–2 years	33	0	1		100	76.4
2–3 years	27	0	0		100	76.4
2–3 years	16	0	0		100	76.4
3–4 years	—	—	—		—	—
4–5 years	—	—	—		—	—
Ramus Grafts	**N° Impl at Risk**	**N° Removed Impl**	**N° Failing Impl**	**Mean PIBR (Range)**	**Survival Rate (%)**	**Success Rate (%)**
Plc – load	31	0	0	0–2 mm	100	100
Load – 1 year	31	0	0		100	100
1 year–2 years	31	0	2		100	93.5
2–3 years	15	0	0		100	93.5
3–4 years	5	0	0		100	93.5
4–5 years	—	—	—		—	—
Calvarial Grafts	**N° Impl at Risk**	**N° Removed Impl**	**N° Failing Impl**	**Mean PIBR (Range)**	**Survival Rate (%)**	**Success Rate (%)**
Plc – load	31	0	0	0–2 mm	100	100
Load – 1 year	31	0	0		100	100
1 year–2 years	31	0	3		100	90.3
2–3 years	9	0	0		100	90.3
3–4 years	6	0	0		100	90.3
4–5 years	—	—	—		—	—

The results from this study seem to demonstrate that, while the overall survival rate of implants is excellent (100%), irrespective to the type of bone used for the reconstruction, peri-implant bone resorption values confirm that better results were obtained in case of reconstruction with highly corticalized bone, such as ramus or calvarial bone. Conversely, iliac bone seems more prone to resorption over time, and results from

TABLE 5 *t*-Tests for the Assessment of the Statistical Significance of the Difference between Peri-Implant Bone Resorption Values Measured for the Study and Control Group According to Type of Graft

Type of Graft	Unpaired *t*-Test Results
Calvarium	The two-tailed *p* value equals 0.1169, By conventional criteria, this difference is considered to be not statistically significant.
Ramus	The two-tailed *p* value equals 0.0200. By conventional criteria, this difference is considered to be statistically significant.
Ilium	The two-tailed *p* value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.
Overall	The two-tailed *p* value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.

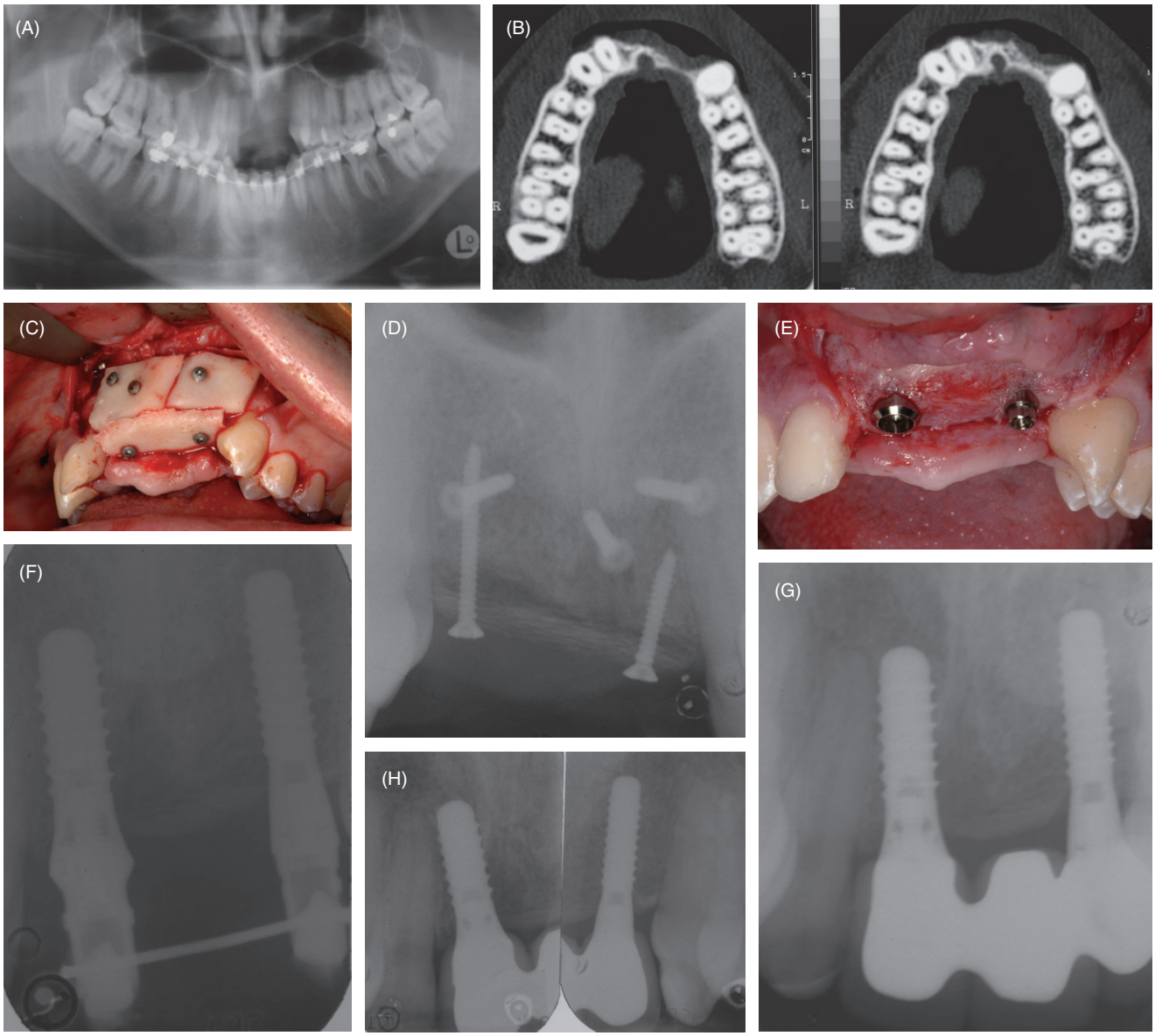

Figure 1 *A* and *B*, Panoramic radiograph shows the vertical defect in the frontal area of the upper maxilla. Computed tomography scans show the severe concomitant horizontal atrophy. *C*, Tridimensional reconstruction of the deficient alveolar ridge with autogenous onlay bone grafts harvested from the mandibular ramus. *D*, Postoperative radiograph demonstrating the correction of the vertical aspect of the defect. *E*, Intraoperative view of the two Tissue Level implants placed in the reconstructed area. *F*, Radiograph taken at the time of implant loading with provisionals. *G*, Radiograph taken at the time of definitive prosthesis cementation. *H*, Control radiograph taken at the end of the observation period (50 months).

this study concerning this aspect are consistent with those reported in recent literature reviews regarding implants placed in iliac grafts.[64,77]

Another factor that may possibly influence resorption of the peri-implant bone, although no sufficient data is available in the literature, might be represented by the connection between implant and abutment. A series of studies advocate that moving the connection between implant and abutment from the edge of the implant shoulder toward the center of the implant (the platform-switching concept) with a narrower abutment may reduce the risk of peri-implant bone resorption.[72–76]

The reasons for this difference are identified in: (1) the migration of the inevitable "microgap" between the abutment and the internal part of the implant, so that the potential inflammatory infiltration is moved away from the crestal bone (the most coronal contact point between bone and implant shoulder); and (2) the improvement of the biological width. These factors seem to lead to a decrease in peri-implant bone

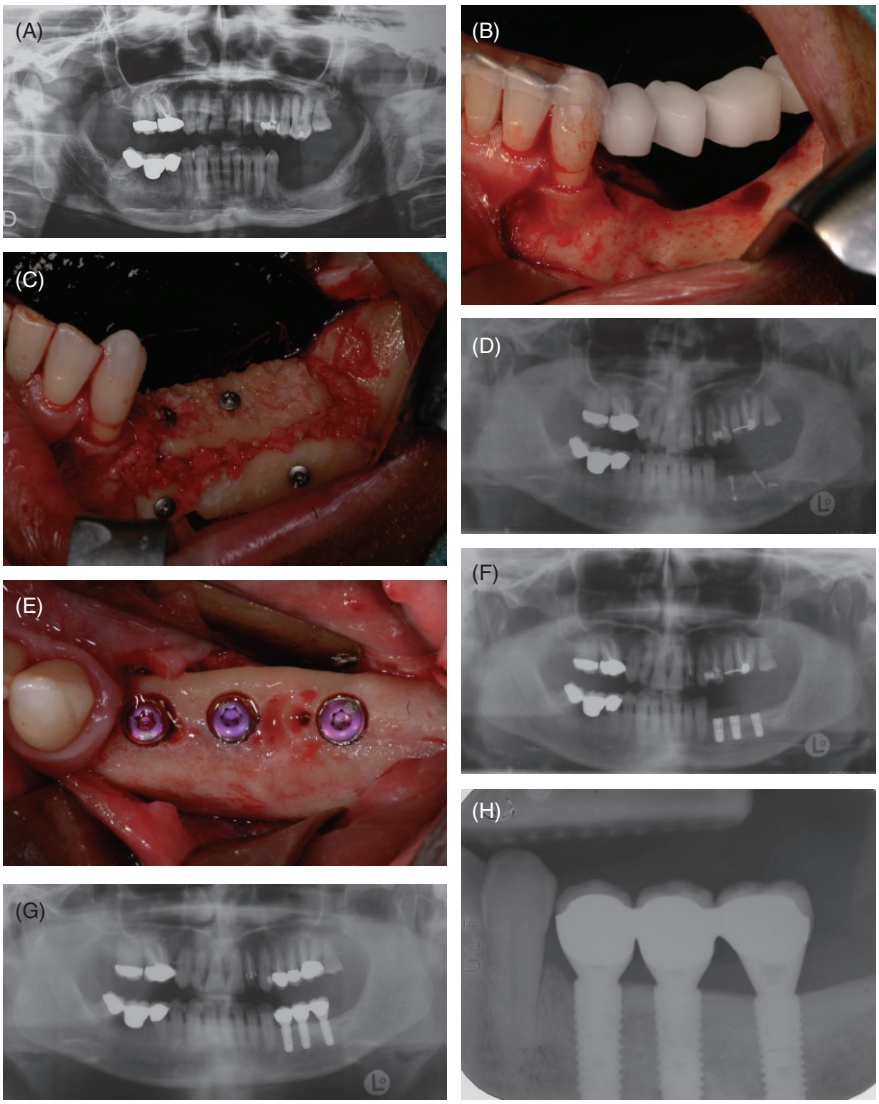

Figure 2 *A*, Panoramic radiograph showing severe tridimensional atrophy of the left posterior mandible. *B* and *C*, The radiographic/surgical stent in place during the first surgical session, to allow for a prosthetic-guided reconstruction. Calvarial onlay grafts are modeled and fixed to the recipient site with titanium microscrews to obtain a complete correction of the defect. *D*, Postoperative radiograph showing the correction obtained. *E*, Bone Level implants placed in the reconstructed area after graft consolidation. *F*, Postoperative radiograph taken after implant placement. *G*, Control radiograph taken at the time of implant loading. *H*, Control radiograph taken at the end of the observation period (36 months).

resorption, as reported in a recent review of the literature.[72] However, these data are derived from implants placed in native bone, while no data are available for implants with a platform-switching design placed in areas previously reconstructed with autogenous bone grafts.

The results from this study, in which Straumann® Bone Level implants (produced according to the platform-switching concept) and Straumann® Tissue Level (produced according to the trans-mucosal concept) were placed in reconstructed bone, seem to demonstrate that, while the overall survival rate of implants is excellent (100%) for both types of implants, peri-implant bone resorption values are significantly lower for Tissue Level implants than for Bone Level implants, in particular in case of implants placed in iliac grafts. These results, although obtained with a retrospective study with a limited patients' sample, appear to be quite surprising, because in contrast with expectations.

Moreover, peri-implant bone resorption around Bone Level implants occurred in a relatively short time span, and it is at present impossible to forecast a progression or a stabilization of peri-implant bone changes. In this study, it was also observed that despite the fact

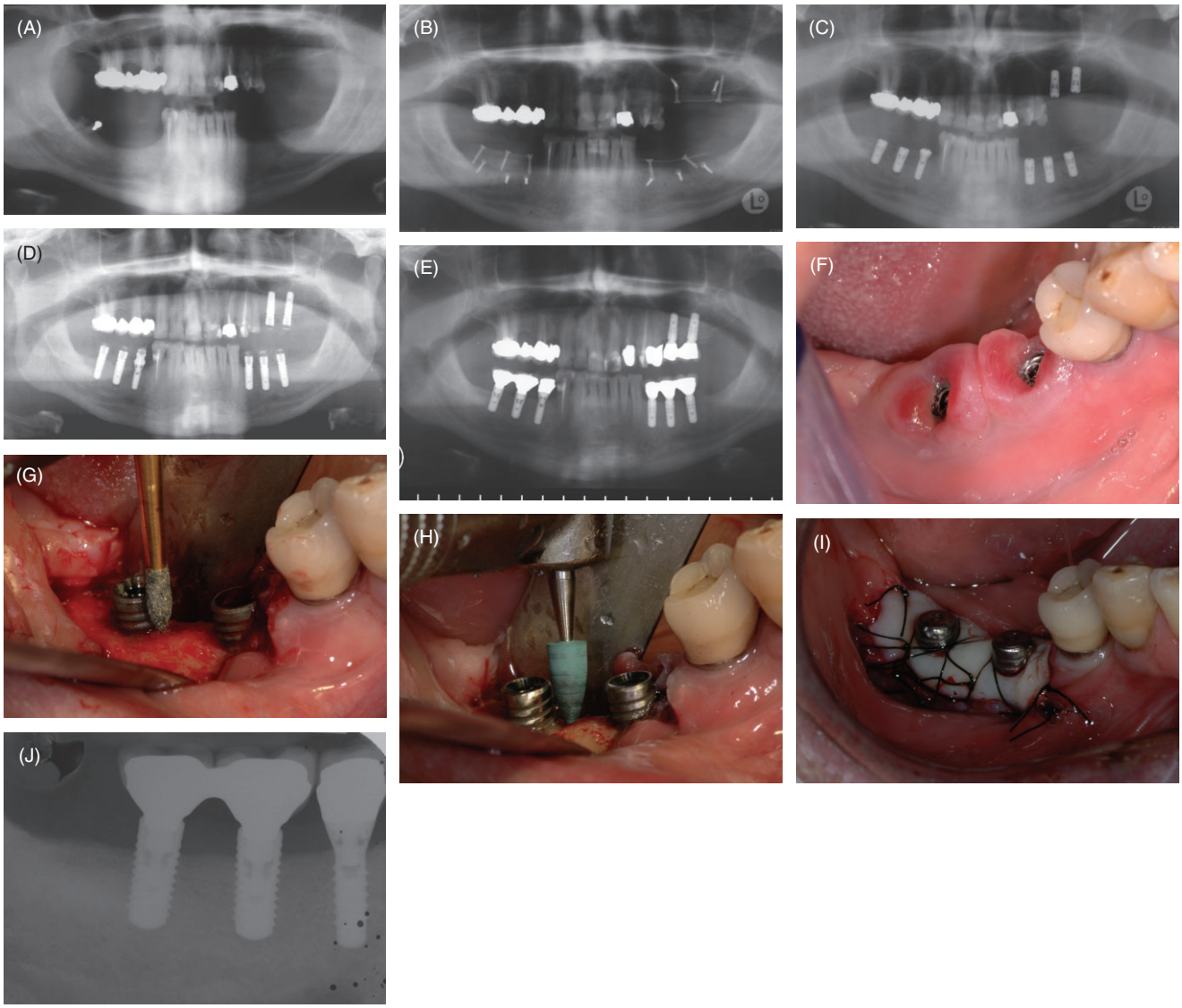

Figure 3 *A*, Panoramic radiograph showing atrophy in the posterior areas of the mandible and in the left lateral-posterior maxilla. *B*, Panoramic radiograph taken after the first surgical session showing the reconstruction of the deficient areas. *C*, Panoramic radiograph taken immediately after implant placement. *D*, Panoramic radiograph taken at the time of implant loading with provisionals. *E*, Panoramic radiograph taken at the time of definitive prostheses cementation. *F*, Hyperplastic soft tissues surrounding the crowns of two implants placed in the right posterior mandible. *G* and *H*, After elevation of a surgical flap, the exposed implant surface is smoothened with diamond burs and rubber tips mounted on slow-speed handpieces. *I*, A keratinized mucosa graft harvested from the palatal vault is sutured around the implants to improve soft tissues quality in the treated area. *J*, Control radiograph showing the extent of the peri-implant bone loss around the treated implants.

that Tissue Level implants had a longer follow-up (range: 12–68 months; mean: 44 months) as compared with Bone Level implants (range: 12–40 months; mean: 22 months), peri-implant bone resorption values were significantly lower at the end of the observation periods in Group A.

This difference, although more evident for implants placed in iliac grafts, was nonetheless significant also for implants placed in cortical grafts such as calvarial and ramus grafts. In fact, mean peri-implant bone resorption values obtained in this study were: 0.21 mm in Group A and 0.35 mm in Group B for implants placed in calvarial grafts; 0.23 mm in Group A and 0.48 in Group B for implants placed in ramus grafts; 0.36 mm and 1.34 mm in Group A and Group B, respectively, for implants placed in iliac grafts. Implant success rates are coherent with these data: in Group A the success rate was 100% irrespective of the type of bone used for the reconstruction, while in Group B the success rate was 93.5% for implants placed in ramus grafts, 90.3% for implants

placed in calvarial grafts, and 76.4% for implants placed in iliac grafts.

The authors believe that, due to the relatively limited patient and implant sample, these results should be, however, interpreted with caution, and that further well-designed experimental and clinical (prospective, randomized, comparative) studies with large samples are needed in order to draw reliable conclusions on these topics.

CONCLUSIONS

Results from this study seem to demonstrate that high survival rates of implants placed in atrophic jaws reconstructed with autogenous onlay bone grafts taken from the ramus, calvarium, and iliac crest can be obtained both with Tissue Level (trans-mucosal design) and Bone Level (platform-switching design). Conversely, as far as peri-implant bone resorption and success rate of implants are concerned, the platform-switching design not only failed to demonstrate a positive effect on crestal bone maintenance, but showed higher values of peri-implant bone resorption as compared with the trans-mucosal design, irrespective of the type of graft but with significantly higher peri-implant bone resorption values for implants placed in iliac grafts.

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