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The use of onlay bone grafting for implant restoration in the extremely atrophic anterior maxilla

A case series

KEYWORDS
Preprosthetic surgery
Autologous bone grafting
Implant survival rate
Alveolar ridge augmentation

SUMMARY

Functional and aesthetic treatments are challenging when ensuring maintain long-term successful prosthetic rehabilitation after alveolar ridge resorption of the anterior maxilla. The goal of this case series was to evaluate implant success rate, prosthetic stability and patient satisfaction in patients treated by onlay bone grafting in atrophic premaxilla. Nineteen patients treated for severe atrophic anterior maxilla by reconstruction using onlay bone grafting and implant restoration between 2002 and 2012 were examined. The surgical procedure was designed to allow the insertion of 49 endosseous implants in the grafted anterior maxillae. Bone resorption and implant success rate were retrospectively evaluated after a follow-up period of 5 years (from 5 to 15 years) subsequent to reconstruction. A questionnaire was the medium used to evaluate patient satisfaction and highlight functional and aesthetic outcomes. The bone grafting success rate was 74%. None of the grafted bones were reported to be infected. Four implants were removed. Implant survival rate was 91.8% after 8.9 years. The permanent reconstruction was fixed in 74% of the cases and removable in 26%. The level of patient satisfaction reported was 6.5/7. In conclusion, his study suggests that onlay bone grafting can be considered a predictable technique for rehabilitation in atrophic premaxilla. The procedure has a high implant survival rate, acceptable bone resorption over time, and promotes graft stability for long-term prosthetic fixation, thereby increasing patient satisfaction.

Introduction

Dental rehabilitation of the atrophic anterior edentulous maxilla presents both functional and aesthetic challenges. A correct alveolar ridge anatomy determines a long-term prosthetic stability and aesthetic outcomes and should thus be obtained by means of preprosthetic surgery to optimize implant insertion. Edentulism leads to vertical and transversal alveolar ridge resorption that prevails over the vestibule side of the anterior maxilla due to a centripetal resorption of the maxillary (Atwood 1971). Similarly, severe atrophic maxillae (class 5 or 6 from Cawood and Howell) (Cawood & Howell 1988) especially result in an insufficient bone volume that prevents favourable implant placement as the maxillary alveolar ridge sits in the same plane as the hard palate. Ridge resorption can also lead

to an inadequate interarch relationship and may further compromise the implant stability with respect to adverse angulations. On top of these challenges, the anterior maxilla is known to be a region that yields inconsistent grafting results, and where causes of bone resorption are not yet fully understood (Jensen & Sindet-Pedersen 1991; Ferri et al. 2008; Lundgren et al. 2008). Whereas accuracy of the implant positioning is essential in providing an aesthetic anterior zone, the stability of the preprosthetic reconstruction is also fundamental to achieve a well-balanced mechanical load and insure long-term aesthetic patient satisfaction.

Bone graft apposition with autogenous bone is the most widely used surgical procedure for reconstruction of the anterior maxilla, regardless of the architectural facial defect (Breine & Branemark 1980; Jensen et al. 1994; Lekholm et al. 1999). Le Fort 1 osteotomy has been proposed as a reconstruction procedure to correct the inter maxillary relationship in both vertically and horizontally dimensions and has also been considered when correcting a sagittal discrepancy (Bell & Buckles 1978) using a one- (Sailer 1989) or two-step procedure from Cawood et al. (Cawood et al. 1994). Autogenous bone is also often harvested from intraoral donor sites (Zeltner et al. 2016; Chappuis et al. 2017) such as the mandibular symphysis region (Garg et al. 1998; Balaji 2002) or the retromolar area (Misch 1996; Cordaro et al. 2002).

Most teams utilize autogenous material from calvarial bone or of iliac crest origin. Combining onlay grafting procedure with autogenous bone material leads to increased bone thickness in extremely resorbed maxillae (Chiapasco et al. 1998; Nystrom et al. 2004). Regardless of the preferred surgical procedure, the goal is a stabile grafted bone, which promotes optimal implant integration and full prosthetic rehabilitation. In this study, maxillary preprosthetic surgery outcomes were analysed in patients having autogenous onlay bone graft performed for atrophic anterior maxillary reconstruction, during a minimum follow-up period of five years after bone grafting.

Materials and methods

Patients

This study presents a retrospective analysis of every consecutive patients who underwent autologous onlay bone grafting of the anterior maxilla before dental implant rehabilitation, in an 11-year period from 2002 up to and including 2012. The patient population presented severe atrophy of the anterior maxilla (Cawood class 5 or 6) (Cawood & Howell 1988), from total to partial edentulous between the two canine teeth and required alveolar ridge augmentation.

All patients underwent surgery in the Department for oral and maxillofacial surgery at the Lille teaching hospital in Lille, France. Initial radiological assessment included orthopantomographic X-ray, cephalometric X-ray, and computed tomography scanning measuring preoperative bone width and height at the level of the canine eminence on both sides. Exclusion criteria included a medical history of head and neck radiotherapy, chemotherapy for malignant tumours, or the use of biomaterials.

Surgical procedures

Depending on the size of the defect, different surgical techniques were utilized, including bone harvesting from cranial calvarium or iliac crest, followed by onlay bone grafting. Depending on patient acceptance after proper information and measured cranium thickness (minimum bone thickness: 7 mm to reduce the risk of cerebral damage), cranial bone was sometimes used. When considering bone harvesting, strips of parietal or iliac cortical bone were harvested along with bone scraping. The thickness of the graft tissue was determined by the thickness of the residual alveolar ridge and depended upon the extent of the rehabilitation project (from reconstructing a single tooth gap to repairing an extended edentulous space with several missing teeth).

The second surgical step was the onlay bone grafting procedure using the framework technique as described for patients with atrophic maxilla limited to the anterior part (Ferri et al. 2008). Miniature bone plates were made using the autologous graft. The incision was typically crestal or located on the palatal side, on a line joining both canine areas. The incision was extended above the papilla of the adjacent teeth surrounding the defect to better spare them. A vestibular counter incision was made on both sides. A mucoperiosteal flap was then raised, giving better access to the recipient site which was drilled. A careful removal of any fibrinous tissue of the anterior wall of the maxilla was performed. Graft bones were modelled to the shape of the recipient site then fixed with microscrews, paying attention to avoid drilling into dead bony spaces. To better preserve the mucosa, sharp edges and bony splinters were drilled as needed (Figs. 1–2).

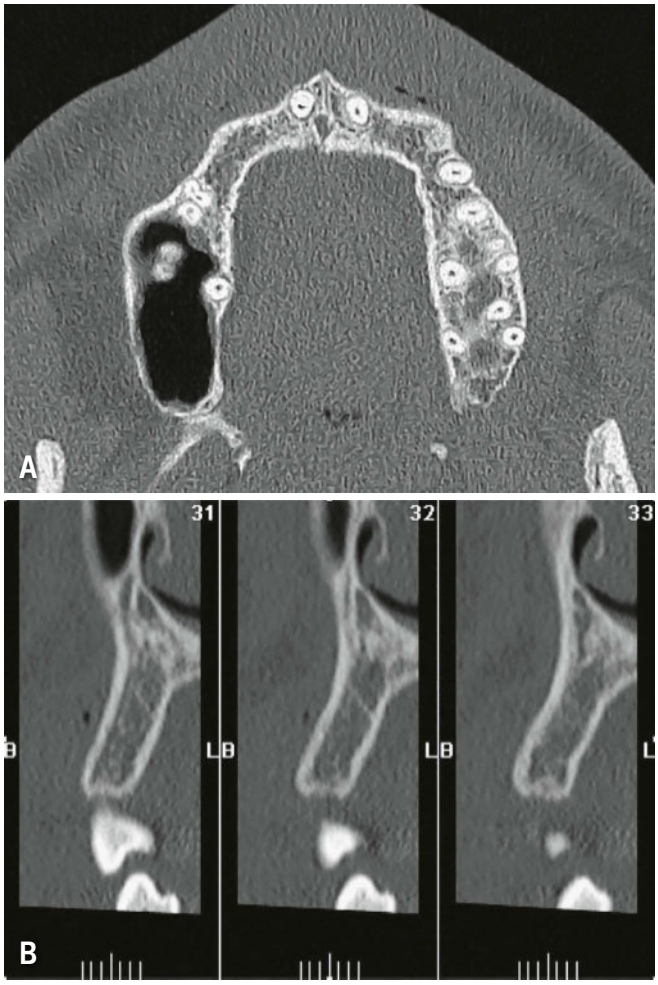

Fig. 1 Preoperative CT scan. Initial bone volume before reconstruction in the anterior maxilla. A) Axial view. B) Sagittal view

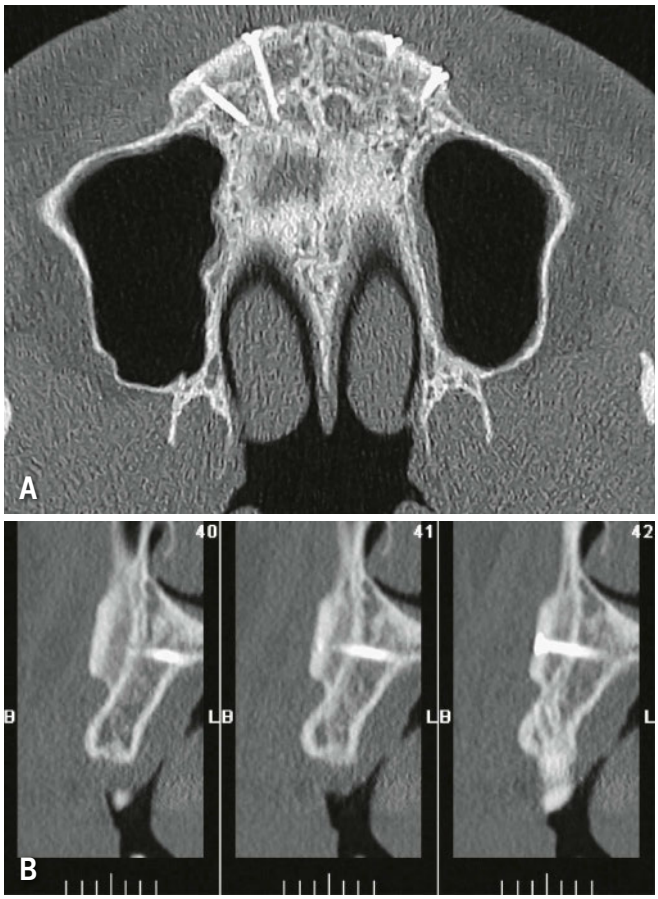

Fig. 2 Postoperative CT scan. Improvement of the quantity of bone volume after onlay bone grafting in the anterior maxilla using the framework procedure. A) Axial view. B) Sagittal view

For all patients, endosseous implant placement was performed six months after bone grafting (Fig. 3). Implant design was chosen depending on the volume of the graft and in accordance with the initial rehabilitation planning. The number, dimensions and distribution of the implants were determined by the prosthetic planning. All placed implants were of external hexagon type with regular Branemark standard platform from *Zimmer, Nobel Biocare* or *Ankylos.* The prosthetic rehabilitation then started six months after the implant placement, once bone integration was obtained, and was adjusted according to the type of preprosthetic surgical procedure (Fig. 4). Abutment placement generally occurred six months after positioning the implants, as a standard procedure in the department.

Clinical and radiographic evaluation

Tomographic scanning evaluation was performed before surgery. Graft stability and vertical and transversal bone levels were measured by computed tomography scanning on the grafted alveolar ridge six months after preprosthetic surgery. The type of prosthetic rehabilitation, the number of endosseous implants placed in the anterior maxilla as well as the average implant surface (in mm^2; calculation method: $\pi \times$ implant diameter [D] $\times$ implant length [L]) were recorded. To evaluate the clinical and radiological outcomes, an orthopantomographic X-ray was performed after surgical reconstruction, and regularly during the follow-up period.

In the cohort of our study, follow-up periods ranged from 5 to 15 years after surgical reconstruction. Patients were divided into three groups according to the duration of follow-up after the bone graft surgery. Group I was composed of 6 patients with a 5-year post-bone-grafting follow-up; group II had 6 patients with a 6- to 10-year post-bone-grafting follow-up; and group III was composed of 7 patients with at least an 11- to 15-year post-bone-grafting follow-up. The resulting radiographic evaluation of bone level improvement, the amount of bone surrounding the peri-implant area, the implant survival rate over time, the prosthetic rehabilitation efficacy, the global aesthetic evaluation and the level of patient satisfaction were analysed and are discussed below.

Radiographic evaluation of bone graft level changes and bone level peri-implant

The marginal bone level was assessed using the crestal bone level as a reference on orthopantomographic X-ray during follow-up. Peri-implant bone loss was calculated using the known implant length, the vertically increased bone graft and bone loss measurement of each implants.

Peri-implant bone loss was also expressed as a percentage of the average implant surface lost over time, using postoperative orthopantomographic X-ray during follow-up. The same investigator performed all X-ray measurements to ensure reproducibility.

The average rate of bone graft resorption over time in the anterior maxilla was determined by calculating the number of exposed implants threads on the measured implant length by

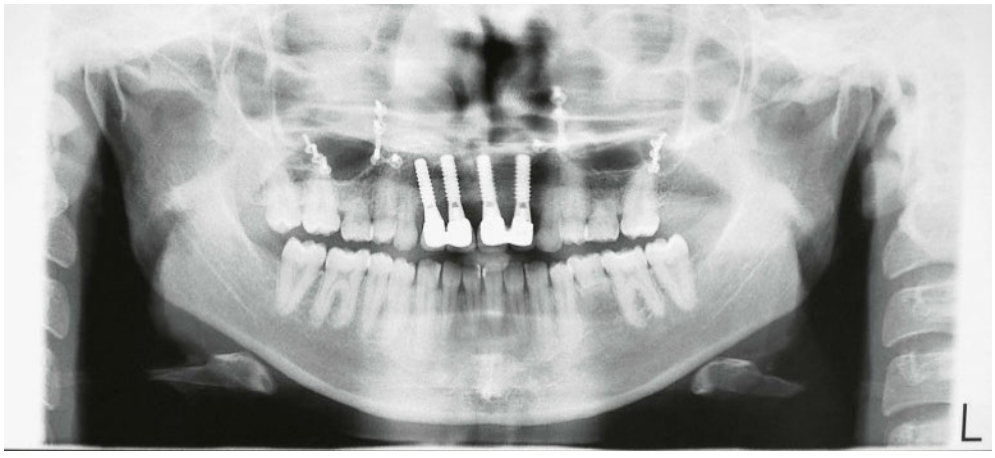

Fig. 3 Orthopantomographic X-ray after implant placement

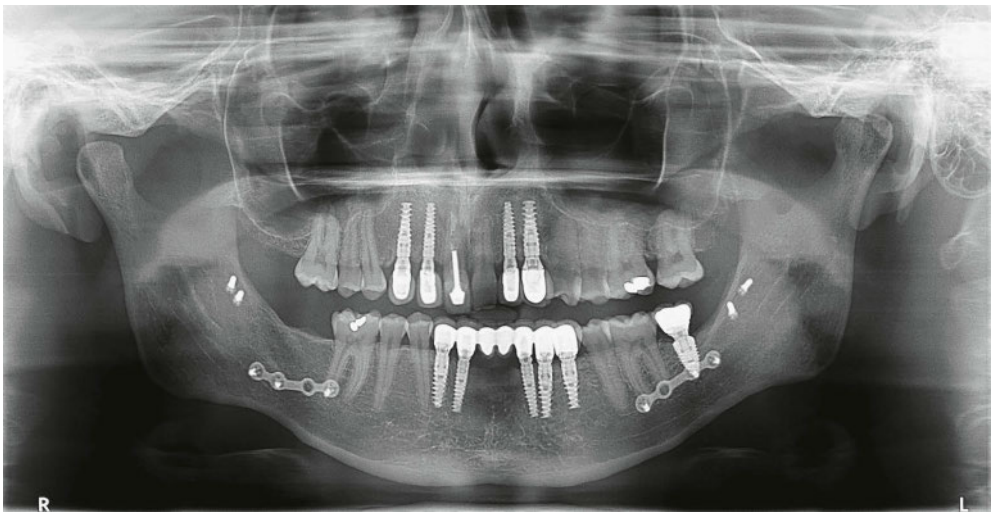

Fig. 4 Postrehabilitation orthopantomographic X-ray

means of the orthopantomographic images. The implant surface loss (%) was defined as the average rate of bone graft resorption times the mean implant surface. Graft failure was defined as the instance when the available quantity of bone did not allow the planned implant placement and/or when the graft was exposed or removed.

Implant survival rate

The implant survival rate was assessed using Albrektsson clinical and radiographic criteria (Albrektsson et al. 1986). The absence of persistent pain or dysesthesia, of mobility, of periimplant infection with suppuration, and of continuous periimplant radiolucency were the main elements of this score. Implant failure was defined by nonfunctional implants in such situations as lost implants, misplaced implants or unloaded implants even if osseointegrated.

Prosthetic evaluation

The type of prosthetic rehabilitation and the quality of restoration were clinically evaluated by assessing the occlusion and verifying the specific position of each implant. The patient was asked about phonetics, mastication, comfort provided by the rehabilitation, and the impact that the procedure had upon his/her social life.

Patient's satisfaction of functions of restorative procedure

Patient satisfaction was established using a dedicated questionnaire (Tab.1) with queries on facial appearance, phonetics and elocution, masticatory functions, comfort provided by the implant and social impact postrehabilitation.

Patient evaluation of aesthetic appearance and functional effectiveness was evaluated on a subjective satisfaction scale ranging from 1 to 7. Responses on the satisfaction scale were scored as follows: 1 = completely unacceptable; 2 = not satisfied; 3 = not completely satisfied; 4 = no change noticed; 5 = somewhat satisfied; 6 = generally satisfied; 7 = completely satisfied.

Results

The study included a total of 19 patients. This sample consisted of 10 female and 9 male patients ranging in age from 15 to 78 years old (mean 37.2 years old). The edentulism resulted from periodontal disease in 42% of cases, hypodontia in 21%, congenital abnormalities for 3 patients (16%), facial traumatism in 16%, and cleft palate in 1 case (5%). There were 10 completely edentulous patients (53%).

The preprosthetic surgical procedure used was an onlay bone graft in 47% of patients and the Le Fort I osteotomy with anterior onlay graft in the other 53% of the patients. Five patients (26%) have received a graft from iliac origin, fourteen patients (74%) have received calvarial bone. No complication was reported at any donor site. In one case, a mucosal dehiscence occurred as a consequence of the volume of the graft.

The average replaced teeth quantity was 4.7 teeth in the anterior maxilla.

The mean follow-up period after bone graft reconstruction was 8.9 years (range: 5–15 years). Fifteen patients (79%) presented severe atrophy with knife-edge edentulous maxillae. Five patients (26%) had been actively smoking around the time of surgery and during follow-up.

Bone graft resorption

The amount of bone level vertical increase was 5.3 mm (760%) on average and the mean transversal increase was 4.8 mm (617%). The observed graft success rate was 74% (14 patients). Of the remaining five cases of graft failure: two were active smokers with complete graft resorption, and three experienced partial resorption. No graft resorption was associated with graft infection or graft exposure. When graft failure was reported, the origin was the iliac crest for two patients and the calvarial bone for three patients.

Among these five failed cases, bone resorption prevailed on the implant placement, requiring another implantation in one patient. In a second case, the use of short implants and the adaptation of the initial fixed prosthetic project with removable prosthesis was proposed. A graft overlay was performed in the final three cases to improve implant placement. For all patients, a prosthetic solution was found with correct implant placement.

Implant survival rate

A total of 49 implants were placed in the anterior maxillae, with an average of 2.6 implants per patient at the anterior site (ranging from 1 to 6). The mean implant diameter was 3.6 mm (range: 3.0–4.8 mm) among *Zimmer* One-Piece 3.0 mmD Implants and *NobelActive* 3.5 mmD Implants. The mean endosseous implant

Tab. I Satisfaction questionnaire of the surgical stages and prosthetic rehabilitation

Scale	1 = completely unacceptable	2 = not satisfied	3 = not completely satisfied	4 = no change noticed	5 = somewhat satisfied	6 = generally satisfied	7 = completely satisfied
Questions about:							
Surgical procedures							
Complication							
Pain							
Support by the professional							
Prosthetic and functional aspects							
Overall restorative procedure							
Comfort							
Mastication							
Elocution							
Temporomandibular joint pain							
Aesthetic aspects							
Facial appearance							
Confident to smile							
Social life impact							
Reconstruction-related quality of life							
Recovery							

length was 11.0 mm (range: 8.0–13.5 mm). The global implant survival rate in our cohort was 91.8%, ranging from 94.6% for calvarial bone to 83.3% when the graft origin is the iliac crest (four implants have been lost on two different patients; 8.1%) (Fig. 5). Figure 5 shows the distribution of the implant survival rate depending on the donor site. Using clinical and radiographic tools, it was determined that 45 implants were osseointegrated in the anterior maxilla.

The only cases of lost implants were found in patients who were smokers. The implant survival rate in the smoking population was 60% compared to 100% for non-smokers.

Clinical and radiographic evaluation

During the 5- to 15-year postsurgery surveillance period, the study had the following distribution:

- group I (5-year postsurgery follow-up): 16 implants, 6 patients.
- group II (6- to 10-year postsurgery follow-up): 11 implants, 6 patients.
- group III (≥11-year postsurgery follow-up): 22 implants, 7 patients.

The endosseous implant surface was 129 mm^2 on average (ranging from 103 to 182 mm^2) at the anterior maxilla (Fig. 6). Figure 6 shows the distribution of the implant surface at the anterior maxilla.

Marginal bone level in the anterior maxilla was 2.10 mm (range: 0.60–8.40 mm). The distribution of the marginal bone level over time was as follow: –1.43 mm at 5 years postsurgery; –1.85 mm after 5 years postsurgery; and –2.80 mm after 11 years postsurgery. The mean peri-implant bone loss using the implant surface was 27 mm^2 or 19% (SD = 27.8–43.8) (Tab. II). Table II shows the percentage of implant surface lost over time during follow-up.

Prosthetic evaluation

All patients in the study have completed the appropriate prosthetic rehabilitation. Fourteen patients (74%) have received fixed bridges and five patients (26%) have received implant-supported overdentures. For the five patients with graft failure, three of them have received fixed prosthetic rehabilitation in the end.

Among the eleven patients suffering from complete edentulism at the maxilla level, five of them (45%) were eligible for a fixed implant bridge. All of the patients with partial edentulism benefitted from a fixed restoration of the anterior maxilla.

Evaluation of patient satisfaction: about functional and aesthetic aspects

Eleven of 19 patients (58%), consisting of one patient from group I (1/6), six patients from group II (6/6) and four patients from group III (4/7), responded to the satisfaction question-

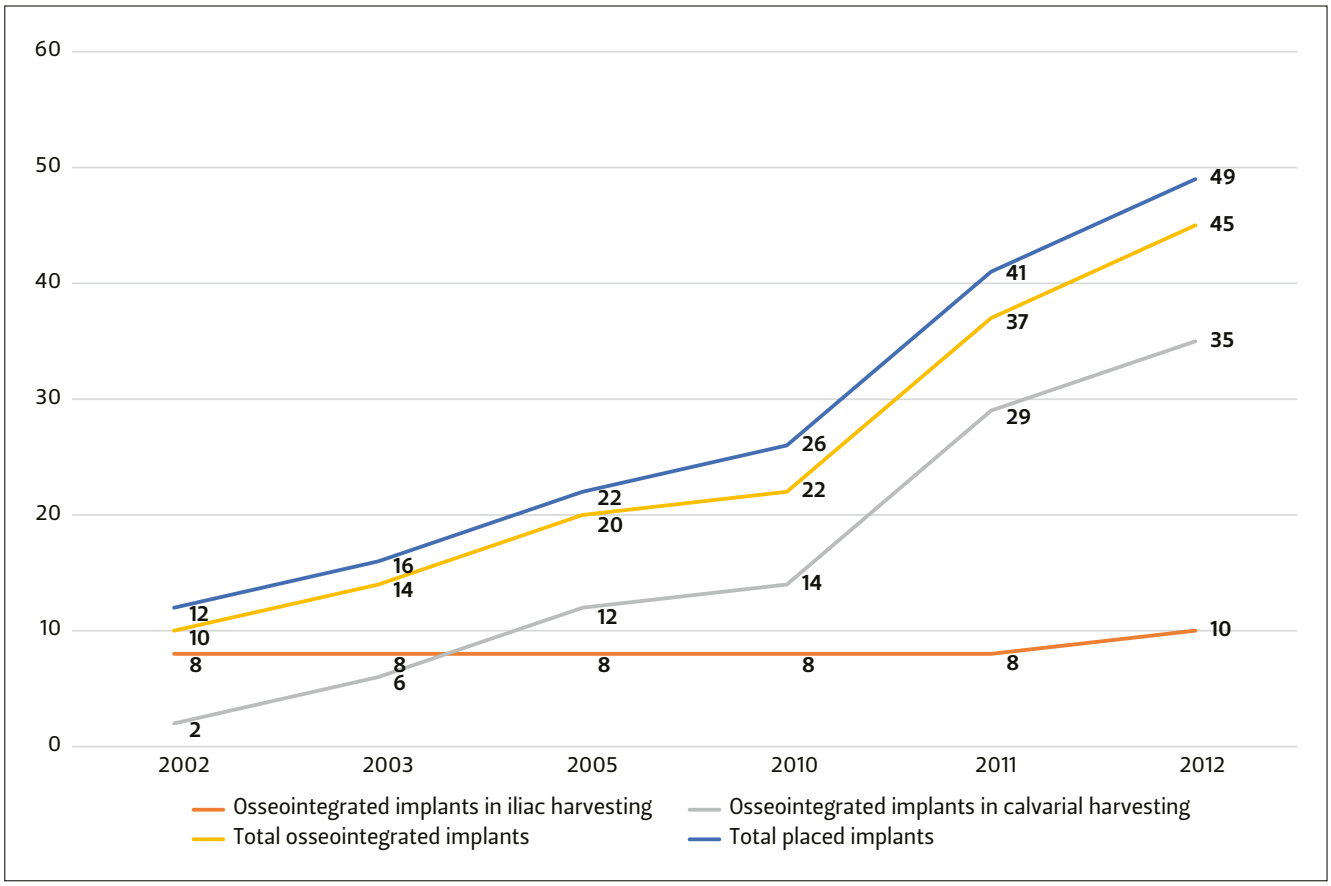

Fig. 5 Distribution of the implant survival rate depending on the donor site

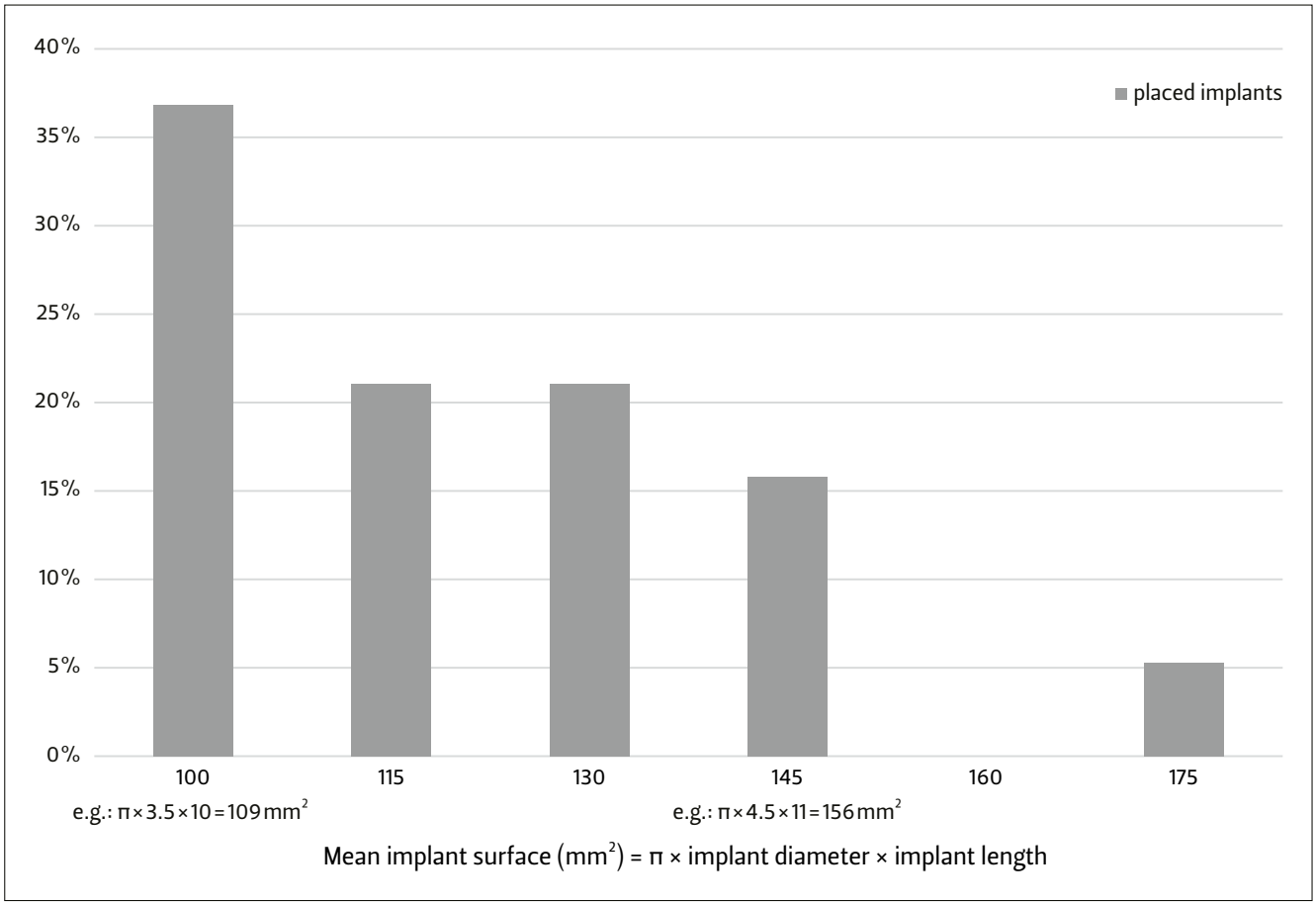

Fig. 6 Distribution of the implant surface at the anterior maxilla

Tab. II Percentage of implant surface loss depending on the follow-up period

Follow-up	Patients	Inserted implants	Average lost implant surface (%) median	Average +/- standard deviation	Min-max
5 years	n = 6	n = 16	0.0 (0.0; 27.5)	15.9 +/- 27.8	0.0–68.0
6–10 years	n = 6	n = 11	0.0 (0.0; 18.1)	19.7 +/- 40.0	0.0–100
11 years or more	n = 7	n = 22	6.3 (0.0; 71.1)	30.6 +/- 43.8	0.0–100
Total	19	49	19.1		

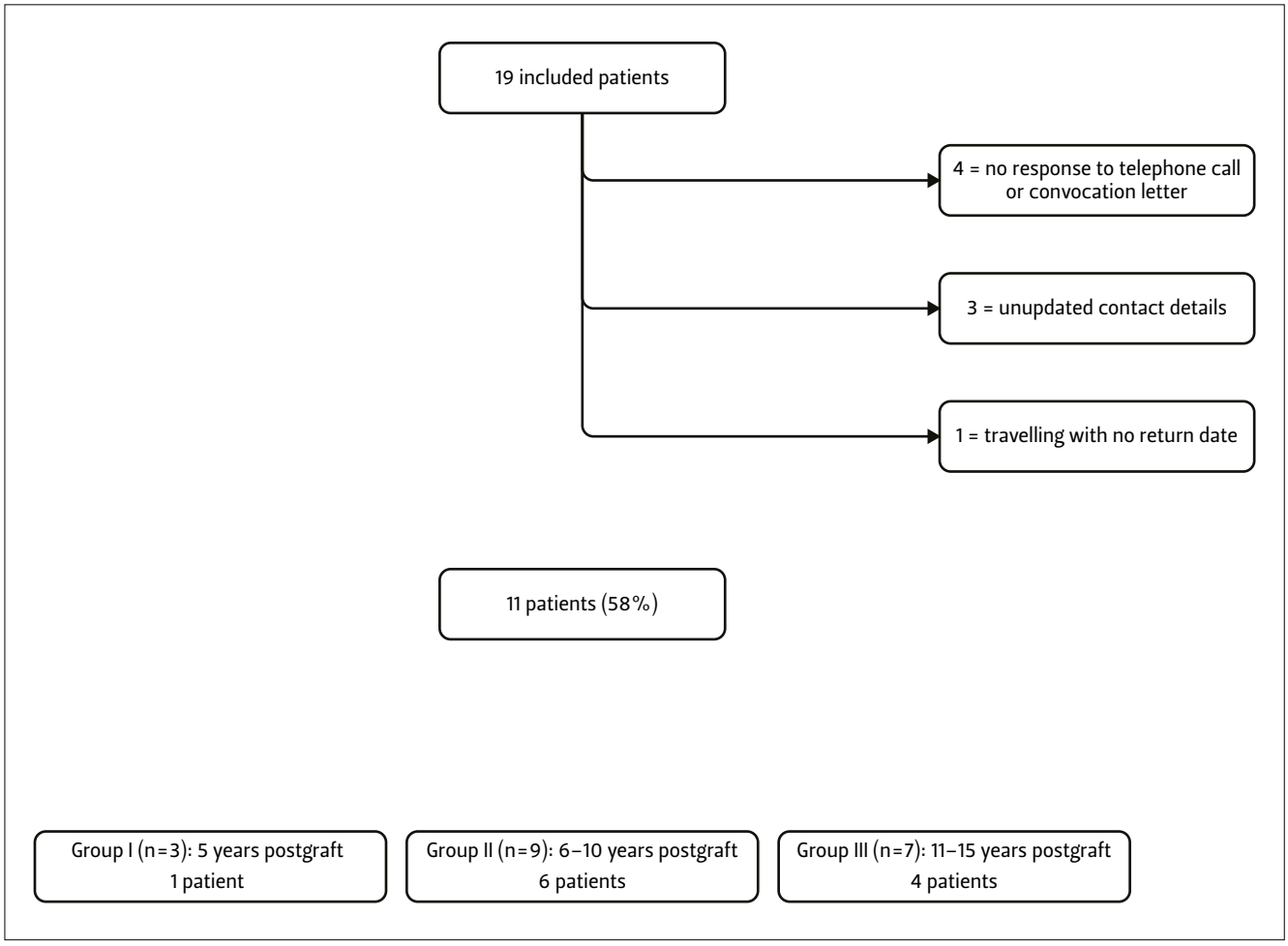

Fig. 7 Flow diagramme for patient's satisfaction questionnaire

Fig. 8 Postrehabilitation occlusal picture

naire. Of the eight non-respondents, four did not answer the survey, three did not have current address information and could not be reached, and one was unavailable due to travel (Fig. 7).

Patient satisfaction was 6.5/7 on average (ranging from 2 to 7). 82% of our study population (9 patients out of 11) was fully satisfied with both the aesthetic and the functional aspects of the provided reconstruction (Fig. 8). Of particular note, there were zero reports of chronic temporomandibular joint pain. One female patient has expressed being "not satisfied" after she was offered a removable overdenture rather than fixed repair.

Discussion

This study demonstrates that onlay bone grafting is a viable treatment option demonstrating a high implant survival rate and acceptable bone resorption over time, based upon measurements of the augmentation procedure. As it is currently understood, onlay bone grafting provides sufficient bone volume prior to implant insertion (Nystrom et al. 2009; Quiles et al. 2015; Depeyre et al. 2016) while reducing surgical complications and enabling a fast recovery. As was demonstrated by Nyström, Chiapasco and Sjöström (Lundgren et al. 2008; Chiapasco et al. 1998; Nystrom et al. 2004; Sjostrom et al. 2007), however, this technique is also accompanied by a high rate of bone resorption. The study showed that a significant amount of bone tissue was grafted and preserved in 74% of cases. In cases of extreme anterior atrophy with significant retrusion associated with complete edentulism, combining Le Fort 1 osteotomy with bone grafting seems to be the only effective treatment that is capable of reaching both fixed bridge and class 1 occlusions (Schlund et al. 2016), thus reducing the amount of graft placed at the anterior maxilla site.

Because the limit of onlay bone grafting appears to be major skeletal inter-arch discrepancy, this technique should not be considered as first-line treatment for cases involving important skeletal dysmorphia or long-lasting edentulism.

Autologous bone harvesting

Some researchers have seemed to demonstrate a preference for using autologous graft from iliac crest origin (Nystrom et al. 2004; Sjostrom et al. 2007) in these procedures. Our department, however, uses primarily calvarial bone, as we believe it offers a higher degree of bone volume (Carinci et al. 2005; Quiles et al. 2015; Depeyre et al. 2016) and that it also enables a more expeditious and simple recovery. Calvarial bone has been providing reliable results as an autologous graft for effective endosseous implant insertion with few complications. These positive results have been supported in a recent study of 211 patients (Depeyre et al. 2016) and of 511 cases (Touzet et al. 2011). Furthermore, calvarial bone is particularly well suited for ridge bone augmentation of the alveolar ridge using vestibular apposition because of the fact that it offers a cortico-membranous block graft morphology (Carinci et al. 2005).

The use of osseoconductive biomaterial as bicalcium phosphate filling-up after calvarial harvesting provides another major benefit as well. It avoids the depression of the scalp (Denglehem et al. 2011), a side effect that can be difficult for patients to cope with. Calvarial harvesting has become more popular since outer-layer reconstruction of the skull is performed in order to suit the morphology of the donor site but also to maintain biochemical features of the skull.

No complications were reported when using calvarial bone as a donor site while pain was observed at the iliac crest. There was only one patient in nineteen who required a remodelling of the donor site. One patient out of the whole cohort has been treated using iliac crest harvesting in 2012 due to poor cranium thickness which would have exposed him to increased cerebral damage. We credit our majority usage of calvarial bone for our strong rate of acceptance.

Patients in the study who benefitted from iliac crest bone grafting were among the oldest of the cohort. The use of this technique corresponded with our department's initial one-step routine procedure utilizing the Sailer technique. The Sailer technique consists of implant placement in conjunction with the grafting surgery (Sailer 1989). Improved results utilizing this technique were obtained by Cawood et al. (Cawood et al. 1994) and then confirmed by Stoelinga et al. (Stoelinga et al. 2000). The procedure has then evolved within our department as a two-step procedure leaving six months between bone grafting and implant placement, to allow for bone consolidation (Triplett & Schow 1996). As strongly advised by Kuchler's work (Kuchler & von Arx 2014), who stated that "the level of evidence is better for the staged approach than for the simultaneous one", we also recommend the two-step procedure. Placing the implant produces a local trauma that potentially increases local vascularization, which could explain the more favourable results reported when utilizing a two-step procedure (Kuchler & von Arx 1014).

To optimize our technique based on the previous discussion, a staged approach using calvarial bone harvesting is preferred when possible, and has now become our routine procedure.

When a small amount of bone is needed, the use of autogenous block grafts harvested from intraoral donor sites has proven to be effective for the reconstruction of horizontal bone defects (Smiler 1996; Garg et al. 1998; Balaji 2002). Harvesting of cortico-cancellous blocks using symphysis or retromolar bone blocks as a donor site offer a well-proven method prior to implant placement (Cordaro et al. 2001; Misch 2011). More recently, authors have shown that "the amount of bone available for the harvesting of cortico-cancellous blocks in the chin region was superior compared to the mandibular retromolar region" (Zeltner et al. 2016), with minimal bone graft resorption in combination with guided bone regeneration (Chappuis et al. 2017). Cone beam computed tomography data now allows for detection of the mandibular incisive canal reducing morbidity in the chin region (Zeltner et al. 2016). However, patients with a severe atrophic maxilla need horizontal and vertical ridge augmentation with calvarial bone which is more suitable in managing larger bone defects.

Bone graft resorption: quality and quantity of the graft

When analysing the amount of bone resorption, we observed a gradual increase in marginal bone level over time, peaking after 11 years postsurgery before reaching a stable value (–1.43 mm in Group I; –1.85 mm in Group II; –2.80 mm in Group III). This is consistent with other study results regarding marginal bone loss (Nystrom et al. 2009) during a 10-year follow-up period (–1.8 mm at 1 year postsurgery; –2.3 mm after 5 years; and –2.4 mm after 10 years). Our results are also comparable to Quiles et al. (Quiles et al. 2015) and slightly better during the first part of the follow-up since they observed marginal bone loss at –1.74 mm after 5 years.

According to a study by Misch and Dietsh (Misch & Dietsh 1991), bone loss during the first-year postsurgery can range anywhere from 0.5 to 3 mm. We believe that the reported bone loss we witnessed was due to resorption, and not to a lack of initial reconstruction. In some extreme cases, resorption approaches 100% of the initial graft tissue. Similar results were found by Ferri et al. (Ferri et al. 2008) and previously by Jensen (Jensen & Sindet-Pedersen 1991), using iliac crest. These results can be explained by the mucosal incision located close to the graft site, which may eventually compromise the vascularization, and can lead to easy graft exposure. Moreover, soft tissues compression also compromises local blood supply. In our study, we used perforated mini bone plates to allow for optimal blood supply and to reduce local soft tissues compression.

Management strategy for maxillary reconstruction in a growing child

As recently advised by Valentini et al. (Valentini et al. 2018), the issue is to identify the best reconstructive options for maxillomandibular defects in a child (<15 years and 3 months). Consideration of the facial growth over time is required while maxillary reconstruction involves particular functions. Paediatric maxilla reconstruction is often associated with malocclusion and jaw discrepancy and prevails on a definitive reconstruction. The paediatric population in our cohort included one 15-year-2-month-old boy requiring anterior maxillary reconstruction after a trauma. His status of skeletal growth was determined by cephalography and hand-wrist radiographs analysing the skeletal maturation (Cronin & Oesterle 1998). Hand-wrist maturation method showed that the boy was near adulthood. He had already permanent dentition without skeletal dysmorphia. Facial symmetry was not engaged during the graft. Furthermore, the reconstruction did not involve a large maxillary defect. Conditions of soft tissues were also satisfactory. The surgical reconstruction was associated with insignificant donor site morbidity. Tolerance was high and associated with correct facial symmetry, normal occlusion and well-tolerated prosthetic restoration.

Implant choice: discussing implant dimensions

Our data supports the fact that the onlay procedure is a consistent technique for placing implants in the atrophic anterior zone, even though this area is considered to be the one which is the most liable to be resorbed. The length of the implant is determined according to the amount of bone graft available, the local conditions postreconstruction, and the type of prosthetic rehabilitation initially chosen. Longer implants can occupy the entire volume of the graft, as described by many authors (Blackburn et al. 2008; Lundgren et al. 2008). The longest length possible was chosen "since a higher failure rate was found with shorter implants" (Keller et al. 1999).

All of the placed implants were standard. Diameters ranged from 3.0 to 4.8 mm, mostly due to bone heterogeneity and variable clinical presentations (Fig. 6). Dimensions were considered to engage the entire volume of the graft. As an example, an 11.0-mm implant length with 3.5-mm diameter which is considered as a suitable biomechanical scenario was mostly used. Very few planned implants needed to be switched with another implant design and most of the inserted implants were in accordance with the prosthetic project as we used a surgical guide. Just one case required placement of short implants (3.0 × 8.0 mm) due to important bone resorption. For one case, lost implants were successfully replaced by zygomatic implants enabling a fixed prosthetic restoration contrary to the initial prosthetic planning (Davo et al. 2007; Kahnberg et al. 2007). No angular implants were placed.

Dealing with systemic risk factors, recruitment of difficult cases: tobacco, Crohn's, oligodontia

Inclusion criteria for this study included active smokers (over 20 cigarettes per day), patients with chronic diseases, patients with poor oral hygiene, and with a low compliance rate. Our population presented several risk factors leading to bone resorption, which may have compromised implant osseointegration and graft stability.

Tobacco

100% of the lost implants occurred in active smokers. We therefore highlight the correlation between a smoking habit and implant failure rate, as we only observed non-osseointegrated implants in smokers (60% implant survival rate in the smoking population; $p < 0.05$). However, smoking is not significantly associated with graft failure, contrary to Nyström's study who showed that marginal bone loss is significantly increased in smokers compared to non-smokers up to the 5-year examination (Nystrom et al. 2009). This difference can instead be explained by our small sample size. The adverse effects of smoking on vascularization are well documented (Bain & Moy 1993) and commonly accepted.

Oligodontia

Out of the six patients suffering from congenital hypodontia (38%), only one graft failure was observed. This result reflects the osteogenic potential of autologous onlay bone graft in such defects (Nystrom et al. 2009). Relevant patients were young and bone graft was therefore the indicated treatment. Implant survival rate was observed to be high. Onlay bone graft is preferred in order to better preserve cortical vascularization if possible (Richardson & Cawood 1991), and this technique is still considered the gold standard for augmentation of the alveolar ridge in congenital hypodontia (Carinci et al. 2005; Li et al. 2011; Breeze et al. 2017).

Crohn's disease

The two patients for whom implants have failed suffered from either rheumatoid arthritis or Crohn's disease, and have received immunomodulator drugs beginning at surgery and through the entire follow-up period. The metabolism of the bone is manifested in inflammatory bowel and articular diseases, leading to bone demineralization (Oostlander et al. 2011; Wu et al. 2012).

If these patients were to be excluded from study analysis, the overall graft success rate would be 84% instead of 74%. This remark contributes to the thinking that inflammatory bowel diseases (IBD) and rheumatoid arthritis should be considered exclusion criteria, even when the condition is stabilized or quiescent.

Implant survival rate

The implant survival rate in our study (91.8%) confirms the reliability of the autologous onlay bone grafting in the anterior maxilla, with improved aesthetic results and superior postsurgery patient satisfaction, which is consistent with similar studies and reviews (Belser et al. 2004; Quiles et al. 2015;

Aghaloo et al. 2016). In a recent systematic review, Aghaloo and Misch (Aghaloo et al. 2016) analysed 16 studies using onlay bone grafting on the edentulous maxilla before implant placement, with a mean implant survival rate of 85.2%. Considering Rasmusson Stability criteria (Rasmusson et al. 2012), "the initial implant stability is probably related more to bone density and preparation technique than the implant design or grafting technique used" (Kuchler & von Arx 2014). In our study, the implant surface had no significant impact either on implant survival rate or on marginal bone resorption rate established by the implant surface loss. There was a distinct relationship between implant survival rate and long-term success rate. We also noted that failure of individual isolated implants did not imply failure of the grafted bone, as observed by other authors (Triplett & Schow 1996). Implant survival rate and implant success rate are not influenced by the quality of the prosthesis, whether fixed or removable. In studies, these results vary from 71.3% to 97% depending on the source (Ferrigno et al. 2002; Karoussis et al. 2004; Weber & Sukotjo 2007).

Prosthetic outcomes

All patients are still wearing their original implant-supported restoration after the final evaluation. Implant-supported fixed prosthesis is proposed as first-line therapy, and was accepted by 74% of the patients in our cohort. For some patients, making the choice of a removable prothesis was influenced by affordability, by a need for improved aesthetic outcomes, or for oral hygiene simplification, as also described by Chiapasco et al. (Chiapasco et al. 2007). Other reasons for selecting retained removable overdentures was prosthetic, particularly in cases with implant loss at the anterior site, so that there could be a reduction in prosthetic cantilever, and for some patients, complete edentulism.

Whatever the contributing factors, treatment priority is still to offer the lightest, simplest, and most aesthetic rehabilitation, while still assessing the significance of the jaw discrepancy's correction.

Aesthetic outcomes: evaluating patient satisfaction

Our study effectively demonstrates that onlay bone grafting promotes implant placement for long-lasting rehabilitation and allows for better function with higher postsurgery satisfaction. Patients were highly satisfied with the facial aesthetics and postreconstruction masticatory function, which is consistent with the findings of other studies (Quiles et al. 2015). Out of the 19 patients we analysed, 7 have required anterior restoration for partial edentulism. It is however, difficult to compare the aesthetic outcome of an implant-supported single-tooth with an implant-supported full-arch restoration. Only one patient was not satisfied by the final result because she expected a fixed restoration instead of removable overdentures. Interestingly, even when implant failure occurred, satisfaction was still high because prosthetic rehabilitation had been successfully performed and the patient had a fixed prosthesis. None of the patients has reported discomfort or pain after the completion of the restoration.

To improve the aesthetic aspect of the procedure, papillae adjacent to the grafted area should be preserved as far as possible, which can be challenging (Buser et al. 2004). Because the subjective and objective evaluation of the aesthetic aspect of the restauration is not widely documented in the literature, predictable factors of positive outcomes have yet to be determined (Belser et al. 2004).

The heterogeneity of the treatments used in our cohort has made it difficult however to standardize our results. In the absence of commonly accepted criteria, we have analysed the line of the smile, the alignment of maxilla central incisors with the line of the canine top, and the degree of upper lip support.

Conclusion

This study demonstrates that onlay bone grafting can be considered a predictable technique for rehabilitation in atrophic premaxilla. The procedure has a high implant survival rate and acceptable bone resorption over time, based on measurements of the augmentation procedure. This procedure promotes graft stability for long-term prosthetic fixation, thereby increasing patient satisfaction.

Consent

All patients have given full informed and written consent for publication and use of pictures.

Conflict of interest

None.

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Zusammenfassung

Einleitung

Die funktionelle und ästhetische Rehabilitation nach Atrophie des Alveolarkamms der anterioren Maxilla ist eine grosse Herausforderung, besonders auch was die erfolgreiche prothetische Langzeitversorgung anbelangt. Die autologe Knochentransplantation ist hierfür die am weitesten verbreitete Behandlungsmethode.

Das Ziel dieser Studie war es, bei Patienten mit starker Atrophie des maxillären Alveolarknochens folgende Parameter zu untersuchen: den knöchernen Volumengewinn der präprothetischen Behandlung, die Erfolgsrate der Implantate, die Stabilität der prothetischen Versorgung und die Patientenzufriedenheit.

Material und Methoden

19 Patienten mit schwerer Atrophie des maxillären Alveolarkamms mit oder ohne Le-Fort-I-Osteotomie, die zwischen 2002 und 2012 behandelt wurden, wurden in die Studie einbezogen. Die Transplantate wurden vom Beckenkamm oder von der Calvaria gewonnen. Alle Patienten erhielten 6 Monate nach Knochentransplantation Implantate, und weitere 6 Monate später eine prothetische Versorgung. Die Beobachtungszeit wurde in drei Gruppen eingeteilt: 5 Jahre, 6–10 Jahre und mehr als 10 Jahre nach Transplantation. Folgende Parameter wurden klinisch und/oder radiologisch untersucht: Verbesserung des Knochenangebots, die Verknöcherung um die Transplantate, die Überlebensrate der Implantate, der prothetische Erfolg und die Ästhetik. Ein Fragebogen wurde von den Patienten ausgefüllt, um deren Zufriedenheit mit dem Behandlungsresultat zu evaluieren.

Resultate
Der mittlere vertikale Knochengewinn war 5,3 mm, der mittlere horizontale 4,8 mm. Die Transplantate wurden bei 5 Patienten (26%) vom Alveolarkamm und bei 14 Patienten (74%) von der Calvaria gewonnen. Es wurden keine Komplikationen an den Entnahmestellen beobachtet. Die Transplantationen ermöglichten es, 49 intraossäre Implantate in die augmentierten Bereiche zu setzen. Der mittlere Knochenverlust um die Implantate betrug 2,1 mm (0,6–8,4 mm). Über die Zeit betrachtet betrug dieser Verlust 1,43 mm nach 5, 1,85 mm nach mehr als 5 und 2,8 mm nach mehr als 11 Jahren. Vier Implantate gingen im Beobachtungszeitraum verloren. Die Überlebensrate der Implantate war 91,8% nach 8,9 Jahren (94,6% mit Knochen der Calvaria, 83,3% mit Hüftknochen). Die Überlebensrate der Implantate bei Rauchern war 60% versus 100% bei Nichtrauchern. Die definitiven Versorgungen waren festsitzend in 74% und abnehmbar in 26% der Fälle. Die Patientenzufriedenheit betrug 6,5 auf einer Skala von 7.

Diskussion
Die Rekonstruktion der atrophierten anterioren Maxilla mittels autologen Knochentransplantaten erlaubt es, ein akzeptables Knochenangebot zu erhalten, um in diesem ästhetisch anspruchsvollen Bereich Zahnimplantate mit einer zufriedenstellenden Überlebensrate setzen zu können. Die untersuchte Technik sichert die Stabilität des Transplantats und erfreut sich einer hohen Patientenzufriedenheit.

Résumé
Introduction
Le traitement fonctionnel et esthétique après résorption de la crête alvéolaire du maxillaire antérieur est un véritable enjeu pour maintenir une réhabilitation prothétique réussie à long terme. L'apposition de greffe osseuse avec de l'os autologue est la procédure chirurgicale la plus largement utilisée pour la reconstruction du maxillaire antérieur.

Le but de cette étude était d'évaluer les gains de volume osseux à la suite de la chirurgie préprothétique, le taux de succès implantaire, la stabilité prothétique et la satisfaction des patients chez des patients ayant une atrophie sévère du prémaxillaire et traités par apposition de greffe osseuse autologue.

Matériels et méthodes
Dix-neuf patients présentant une atrophie osseuse sévère au maxillaire antérieur ont bénéficié d'une reconstruction chirurgicale par apposition de greffe osseuse autologue avec ou sans ostéotomie de Le Fort I de 2002 à 2012. Les sites de prélèvement étaient la crête iliaque antérieure ou le calvarium. Tous les patients ont reçu une réhabilitation implantaire six mois après la greffe osseuse, suivie d'une restauration prothétique six mois après la pose d'implants. Les périodes de suivi ont été divisées en trois groupes de cinq ans, six à dix ans et plus de dix ans après reconstruction chirurgicale. Les paramètres suivants ont été analysés rétrospectivement par évaluation clinique et radiographique: l'amélioration du niveau osseux disponible, la quantité d'os autour de la zone péri-implantaire, le taux de survie implantaire, l'efficacité de la réhabilitation prothétique, l'évaluation esthétique globale. Un questionnaire a été utilisé pour évaluer la satisfaction des patients et a mis en évidence les résultats fonctionnels et esthétiques.

Résultats
Le gain vertical du niveau osseux du prémaxillaire était en moyenne de 5,3 mm et de 4,8 mm pour le gain horizontal après la greffe d'apposition. L'origine du prélèvement était iliaque chez 5 patients (26 %) et calvariale chez 14 patients (74 %). Aucune complication n'a été observée sur le site donneur. Le taux de réussite de la greffe osseuse était de 74 %. Aucun échec de greffe par infection n'a été observé. La procédure chirurgicale a été conçue pour permettre l'insertion de 49 implants intraosseux aux maxillaires antérieurs préalablement greffés. La perte osseuse péri-implantaire moyenne au prémaxillaire était de 2,10 mm (0,60–8,40 mm). Le niveau osseux marginal au cours du suivi était de –1,43 mm à cinq ans ; –1,85 mm après cinq ans ; et de –2,80 mm après onze ans. Quatre implants ont dû être déposés. Le taux de survie implantaire était de 91,8 % après 8,9 ans (94,6 % dans l'os calvarial, 83,3 % dans la crête iliaque). Le taux de survie implantaire parmi les fumeurs était de 60 % contre 100% chez les non-fumeurs. La prothèse définitive était fixe dans 74% des cas et amovible dans seulement 26 %. Le niveau de satisfaction des patients était de 6,5/7.

Discussion
La réhabilitation du maxillaire antérieur par greffe osseuse autologue d'apposition permet d'obtenir un volume osseux acceptable pour permettre une insertion optimale des implants dentaires dans cette zone esthétique avec un taux de survie implantaire satisfaisant. Cette technique assure la stabilité du greffon permettant d'obtenir une réhabilitation prothétique implantaire stable et esthétique à long terme tout en répondant à la satisfaction des patients.

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