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Retrospective evaluation of 211 patients with maxillofacial reconstruction using parietal bone graft for implants insertion

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A B S T R A C T

Purpose: For a century, autologous bone grafts have been used in maxillofacial reconstruction. The ideal bone harvest site and grafting procedure remains a point of contention in regards to obtaining optimal long-term results with sufficient bone quantity and density without serious complications. More recently, confronted with growing patient requests and biomaterials development, maxillofacial surgeons and dentists have been considering these issues as they relate to pre-implant surgery. This study sought to evaluate implant success rate and complications following pre-implant surgery with parietal bone grafting.
Materials and methods: A retrospective study was carried out on patients who underwent maxillofacial reconstruction of different sites (symphysis, mandibular corpus, maxillary sinus and premaxilla) for the purpose of implant insertion.
Results: 311 procedures in 211 patients were included. The implant osseointegration rate was around 95%. Clinical follow-up ranged from 10 months to 11 years. A secondary procedure was performed in 6.1% of cases and we noted no serious complications at the harvest site.
Discussion: With good revascularization and osseointegration of the graft, the use of parietal bone leads to an implant success rate similar to that seen in the literature. Moreover, the use of this material results in few infections and low bone resorption provided there is strict immobilization of the graft and no tension on the soft tissue sutures.
Conclusion: Parietal bone grafts technique possess the required qualities for the success of implant surgery, offering results at least as interesting as others using autogenous bone and with no serious complications on donor site.

1. Introduction

With the advent of implant surgery, among the key determining factors identified for implant success are both the bone volume and density. Thus, implant success rate is closely related to the type of graft used. Currently, biomaterials present an attractive alternative to autologous bone grafts by providing new bone formation without the need for a donor harvest site. However, due to their very high success rate and low incidence of donor site morbidity, autologous non-vascularized grafts remain the gold standard for pre-implantation surgery (Raoul et al., 2009). Autologous bone grafts are then reserved for reconstruction following massive jaw resection and not for alveolar bone augmentation for the purpose of implant insertion. Maxillofacial surgeons and dentists have sought to find the best compromise between bone quantity and density, the capacity for implant osseointegration in the chosen graft and the possible harvest site complications. We prefer the parietal bone graft, due to the high bone density and possibility of a large-volume sample. It appears to be suitable for any case requiring bone

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augmentation in the maxillofacial area for the purpose of implant insertion. Orthognathic surgery may also be performed during bone grafting (Ferri et al., 2010). Parietal bone is, in our experience, a very good grafting material, providing a clinically very high bone density in sinus grafting (Ferri et al., 2008). In this study, we sought to evaluate the use of parietal grafts for alveolar bone augmentation in different anatomical sites.

We performed a retrospective study of 211 patients who had undergone maxillo-mandibular reconstructions over a 10-year period, by means of a parietal bone graft allowing for dental implant insertion. The study considered this graft material in the reconstruction of several areas: symphysis, mandibular corpus, maxillary sinus, and premaxilla. The aim of this study was to evaluate this material, by assessing implant success rate, donor site complications, and need for secondary grafting due to eventual insufficiency of bone from the first procedure.

2. Materials and methods

2.1. Study design and inclusion/exclusion criteria

Consecutive patients who had undergone maxillo-mandibular alveolar bone reconstructions by means of a parietal bone graft allowing for dental implant insertion were included from 2003 to 2014. The areas grafted were the symphysis, mandibular corpus, maxillary sinus, and premaxilla. Due to the retrospective nature of this study, it was granted an exemption by the University of Lille institutional review board.

The etiologies of the absent teeth were congenital absence, post-trauma, and dental or periodontal infection. Congenital missing teeth in cleft cases were excluded from the study because this situation also involves soft tissue management associated to bone grafting. Neoplastic etiologies were excluded because most of them underwent post-surgery radiotherapy. In those cases, osseous vascularized flap remain the gold standard.

2.2. Surgical procedure

In all cases, surgery was performed under general anesthesia, and patients stayed at the hospital for 1 night. The reconstruction technique involved the use of a parietal bone graft and was adapted to the specific area and was as follows:

- Onlay grafting for the corpus, the premaxilla (Fig. 1), and the symphysis, in accordance with the framework technique, which results in a high density of newly reconstructed bone (Ferri et al., 2008). The bone harvesting was performed using the technique outlined by Tulasne (1999) (Figs. 2 and 3).
- Inlay grafting for the sinus (Figs. 4 and 5), by the classic approach, or by means of a Le Fort I osteotomy when jaw discrepancy was present, according to the guideline previously published (Ferri et al., 2008). In this area, the reconstruction was performed both to achieve maximum bone density and to treat the jaw discrepancy.

2.3. Post-surgical evaluation

All patients were regularly evaluated after surgery up to 6 months and the performance of a computed tomography scan. A secondary procedure was indicated when the result (bone height and density) was judged to be insufficient on imaging. If the bone level was sufficient, the osteosynthesis material was removed, and implants were inserted at the same time.

Fig. 1. Example of a pre-operative dental computed tomography scan. A large premaxillary bony defect is shown. We would perform a three-dimensional onlay graft, with a complex framework structure.

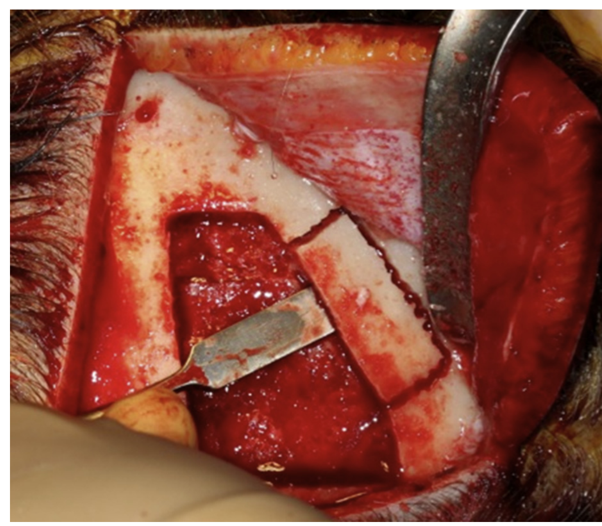

Fig. 2. Parietal bone harvest. Thin osteotome is used to split large parts of outer cortex, permitting large framework reconstruction.

Fig. 3. Parietal bone graft. Large bands are put aside for framework structure construction. Bone chips will fill the framework defects.

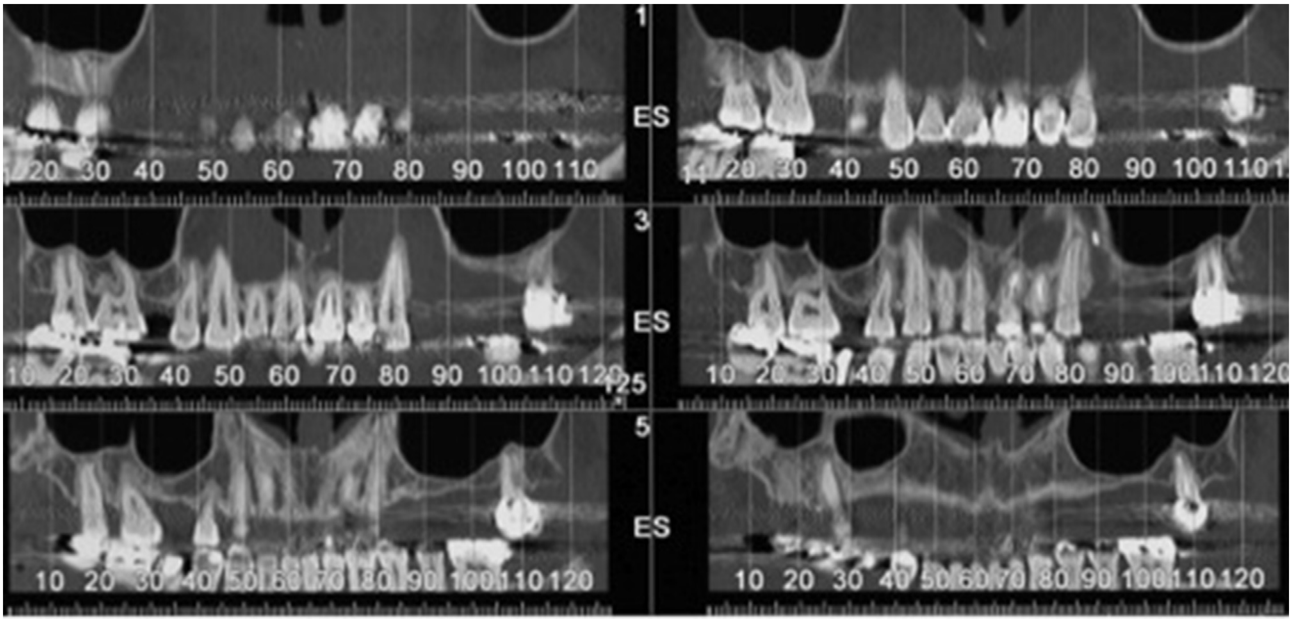

Fig. 4. Example of a pre-operative dental computed tomography scan. Lateral maxilla bony loss in three dimensions is observed. On the right side, we would perform a simple sinus lift; on the left side, we would combine a sinus lift and onlay graft.

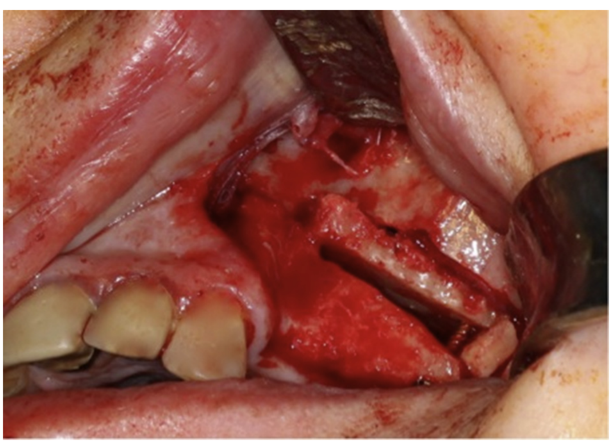

Fig. 5. Sinus lift procedure. A long screw immobilizes the association between bone strips and bone chips, avoiding any sinus mucosal wound. The screw will be removed during implant placement.

In the majority of cases, for unitary rehabilitation procedure, implants used were standard implants, with a 3.5- or 4-mm diameter and a 10- or 12-mm length for maxillary, 8- or 10-mm length for mandible (depending of bone density on CT scan) (Table 1). In case of partial or total rehabilitation using a bridge or bar retained denture, decision was individually discussed regarding its location.

Table 1
Implants used in our procedure of partial rehabilitation: diameter and length of the implants with regard to their site.

Maxillary site							
Tooth position	1	2	3	4	5	6	7
Implant diameter (in mm)	3.5	3.0	4.0	3.5	3.5	4.5	4.5
Implant length (in mm)	10	10	12	10	10	10	10
Mandibular site							
Tooth position	1	2	3	4	5	6	7
Implant diameter (in mm)	3.0	3.0	3.5	3.5	3.5	4.5	4.5
Implant length (in mm)	10	10	12	10	10	8	8

*±2 mm based on bone density on CT scan.

Additional biomaterial grafting during implant insertion, at the maxillary sinus area, was not considered as a secondary grafting procedure, because primary stability of the implant was possible. We consider this procedure to be cosmetic periodontal management.

Data were collected during follow-up of the patients. First, the study considered reconstructed area data: anatomical localization, reconstruction techniques, missing teeth etiologies, number of implants inserted, percentage of integration, secondary procedure occurrence, and prosthesis. Second, frequent harvest site complications were measured: neurosurgical complications, post-operative pain, skull depression, alopecia, and scar dysesthesia.

3. Results

As shown in Table 2, a total of 311 procedures were performed in 211 patients, in the symphysis menti (10 procedures; 3.2%), mandibular corpus (35 procedures; 11.2%), maxillary sinus (110 procedures; 35.4%), and premaxilla (156 procedures; 50.2%).

Etiologies of missing teeth were dental/periodontal infection related (100 patients, 47.3%), post-traumatic (71 patients; 33.6%), and congenital (40 patients; 18.9%).

The number of secondary procedures required due to insufficient bone for implant insertion was highest in the symphysial area (3 [33%]). For the corpus, 4 secondary procedures (11%) were performed, due to bone exposure resulting in an inadequate final result. In regard to the sinus, the number of secondary procedures was low (1.8%), and these were performed due to infection of the graft. The premaxilla had a rate of secondary procedure of 6.4%, resulting from resorption in this area.

Clinical follow-up of all patients ranged from 10 months to 11 years after the first surgery. The average rate of implant osseointegration was high, at 95%. The maximum rate of 96% was found for the sinus and the premaxilla areas, whereas the rates of 95% and 93% were noted for the corpus and the symphysis, respectively.

The prosthodontic outcome was achieved by fixed bridge in all patients except in those in whom major atrophy necessitated a Le Fort I osteotomy. In these patients, a denture on bar was set up.

Table 2
Implant surgery performed: number of reconstructions performed, technique used, number of secondary procedures, number of implants inserted, percentage of implant integration, and prosthesis type, according to site of reconstruction.

Grafted area	Number of procedures	Surgical technique	Number of secondary procedures	Number of implants inserted	Percentage of integration	Prosthesis type
Symphysis	10	Onlay grafting	3 (33%)	21	93%	Fixed bridge
Mandibular corpus	35	Onlay grafting	4 (11%)	105	95%	Fixed bridge
Maxillary sinus	110	Inlay grafting and/or Le Fort 1 osteotomy	2 (1.8%)	381	96%	Fixed bridge/implants retained denture
Premaxilla	156	Onlay grafting	10 (6.4%)	200	96%	Fixed bridge
Total	311		19 (6.1%)	707	95%	

An analysis of parietal bone harvest complications (Table 3) demonstrated a depression at all donor sites when no reconstruction was performed. No neurosurgical complications were encountered. Five patients experienced localized alopecia around the scar (2.4%), and 3 patients reported dysesthesias of the scar itself (3.6%).

4. Discussion

This study highlights that parietal bone grafts offer convincing results in maxillofacial reconstruction, given the safe harvesting procedure and high rate of implant integration in a range of grafted areas. We observed a high success rate for implant insertion (95%), which was comparable with the rates recorded in the literature (Iizuka et al., 2004; Bianchi et al., 2004; Baccar et al., 2005; Smolka et al., 2006; Ferri et al., 2008; Gutta and Waite, 2009; Kamal et al., 2009).

The relatively small number of cases included is due to the profile of the patients referred to our department. Very few basic situations are encountered, with almost all patients presenting with several missing teeth (average 3.35 implants/patient) and no unitary situation. Furthermore, the etiologies of the bony deficit were complex, mainly caused by periodontitis (100 cases), followed by traumatic causes (71 cases) and agenesis (40 cases).

According to the literature, autologous bone grafts are considered preferable to alloplastic grafts for implant placement (Maves and Matt, 1986). In their study, Verhoeven et al. (2000) compared the results of different grafts for implant surgery, focusing on surgical technique and graft origin, and concluded that the type of bone used was the most important factor influencing the success of a graft (Verhoeven et al., 2000). Membranous bone grafts produce a higher bone density and undergo lower resorption than endochondral bone (Zins and Whitaker, 1983; Kusiak et al., 1985; Hardesty and Marsh, 1990) in maxillofacial reconstruction. This has been confirmed by many studies comparing results of iliac crest grafts (Haers et al., 1991; Vermeeren et al., 1996; Verhoeven et al., 2000; Joos and Kleinheinz, 2000; Raghoebar et al., 2001), costal grafts (Kondell et al., 1996; Pogrel, 1988) and parietal grafts (Smolka et al., 2006). This difference could be explained partly by the earlier revascularization observed in membranous bone (Kusiak et al., 1985). Moreover, histological studies demonstrate very good osseointegration of parietal bone grafts in maxillary reconstructions (Orsini et al., 2003; Le Lorc'h-Bukiet et al., 2005). We sampled one of our grafts after 6 months, during implant placement. Histological analysis showed good bone vitality and density, rich revascularization, and reconstitution of the local bone micro architecture (Fig. 6).

Techniques using osteoinductive recombinant human bone morphogenetic protein-2 (rhBMP-2) were approved by the U.S. Food and Drug Administration (FDA) in 2007 for localized alveolar ridge and maxillary sinus floor augmentation. In a study of 5 patients with localized anterior maxillary atrophy, rhBMP-2 was used with titanium mesh and showed interesting results (Ribeiro Filho et al., 2015). However, recent systematic reviews highlighted that sinus augmentation following autogenous graft was significantly greater than for rhBMP-2 (Sheikh et al., 2015; Freitas et al., 2015; Kelly et al., 2015). Herford and Bell in 2009 (Bell et al., 2009; Herford et al., 2009), discussed the interest of rhBMP-2 as an alternative for reconstructing mandibular continuity defects when soft tissues are preserved, but no consensus was established.

Regarding the complexity of our extended atrophy situations, implicating both maxillaries, we made the choice of a validated autologous bone graft technique, following an IAOFR consensus report (Cawood and Stoelinga, 2006).

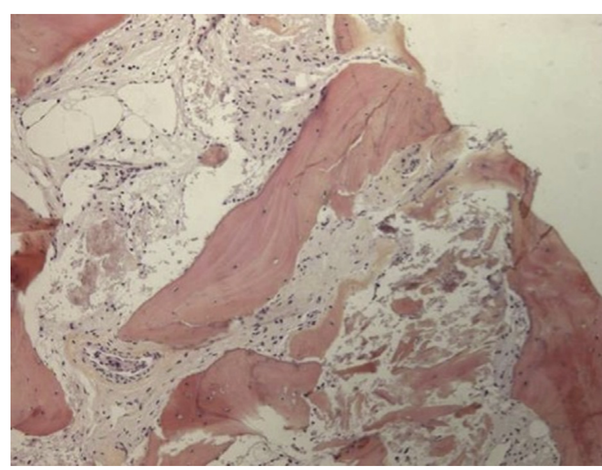

Fig. 6. Parietal bone graft sampled during implant insertion. Histological results after 6 months of osseointegration. Magnification × 100; hematoxylin-eosin-safran stain.

Table 3
Parietal bone graft harvesting complications, with or without reconstruction with bicalcium phosphate (Medtronic).

Harvest complications	Post-operative pain	Skull depression	Neurosurgical complications	Alopecia	Scar dysesthesia
Reconstruction with bicalcium phosphate (BCP) (β-TCP + hydroxy-apatitis)	None	None (129)	None	3 cases with a scar over 5 mm (but under 10 mm)	2 cases
Without reconstruction	None	All patients (82)	None	2 cases with a scar over 5 mm (but under 10 mm)	1 case

Moreover, although techniques of maxillary reconstruction using BMP-2 could be realized under local anesthesia and without hospitalization, it seems that autologous bone grafts techniques are associated with a lower cost. Indeed, our procedure required a 1-night hospitalization, one operating room access, and general anesthesia, all included in the hospital charge (1457,00€). The harvested site was reconstructed by biomaterial BCP the price of which is about 167.70€ unitary. The higher price of BMP-2 techniques is essentially due to the product procurement costs. Calori et al. (2013) also support this statement in a study about cost effectiveness of tibial non-union treatment. They compared, at two Italian centers, the price of two procedures: one using rhBMP-7, the other autologous bone grafts. These two procedures required hospitalization, and the medical costs incurred during the hospitalization associated with treatment were on average 3091.21€ higher in patients treated with rhBMP-7.

In our study, parietal bone harvesting caused no serious complications, which is consistent with previous studies (Touzet et al., 2011). The morbidity of the procedure is virtually absent in experienced hands. The most frequent patient complaint pertains to depression at the donor site, which can be corrected through the use of an alloplastic filling, such as the biomaterial BCP, or autologous reconstruction (Denglehem et al., 2011) (Fig. 7). There is no significant post-operative pain, as often experienced with the mandibular, iliac crest, or costal graft. The procedure is comparable with a standard surgical procedure and may possibly be performed under simple sedation and ambulatory hospitalization.

The technical aspects of the surgical procedure contribute to the high success rate of bone grafts. We find that bone graft resorption is highly correlated with bone exposure after the procedure. The choice of the incision location is a likely determinant of graft success. It is based on the quality of the mucosa itself. Incisions into fibrous tissues should be avoided, as they increase the risk of impaired closure due to poor vascularization and low elasticity. Moreover, incisions should be performed in the alveolar crest bone area only when a tight closure can be performed (except for Le Fort I procedures involving a superior vestibular incision). It is imperative that the grafting site not be under tension from the soft tissues. This must be ensured by determining that there is adequate mucosal coverage or by using a local flap (Fig. 8). Even with a perfect closure, prophylactic antibiotic treatment is recommended.

Another cause of bone resorption is mobility of the graft. Phillips and Rahn clearly demonstrated this phenomenon in adult sheep (Phillips and Rahn, 1988, 1990). As described by Ferri et al. (2008), a solid framework must be built. Screws anchored in native bone, except in the case of the inlay grafting technique, should secure the graft. The screws will be removed during the implant placement (Fig. 9).

Fig. 7. Harvest site reconstruction. A bicalcium phosphate mix reconstructs the defect in order to avoid esthetic sequellae. Perfect bone restoration is achieved.

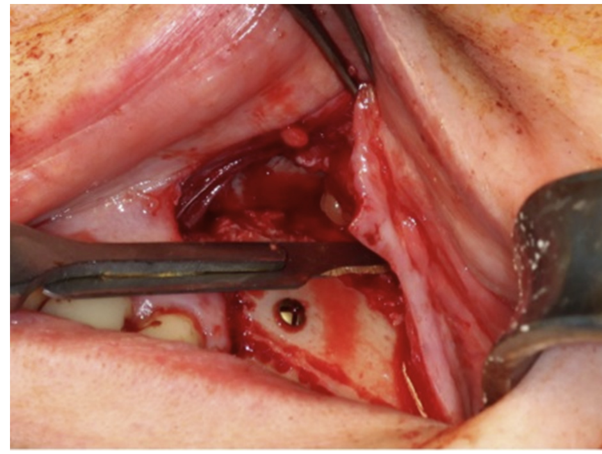

Fig. 8. Local mucosal flap for a complete closure, decreasing infection rates. Clinical and radiological parietal bone graft appearance. The graft is perfectly osteointegrated. Screws could easily be removed during implant insertion.

No significant difference in the success rate was observed for the various grafted sites. However, the success rate was higher for the premaxilla and the sinus sites than for the mandible. Local specificities, mandibular and maxillary, leading to these minor variations have been analyzed.

At the mandible, reconstructions of the symphysis area rarely require bone grafting; it is indicated when the remaining symphysial bone is so reduced that a 10-mm-long implant cannot be inserted. A source of bone graft failure may be the grafted volume being too large for the symphysial remaining bone and its poor vascularization. The second possible cause is exposure of grafted bone under tension from the soft tissue of the lip. In cases in which high resorption occurred, it was noted that the mucosal flap covering the graft originated from the lip, which is always highly mobile and often a source of tension.

The highest percentage of secondary procedures (33%) occurring at the symphysis may be explained by the technical difficulties encountered at this location, especially when adjacent teeth are present. In this situation, there is a vast difference in the bony level between the remaining alveolar bone and the native bone surrounding the remaining teeth. A three-dimensional reconstruction is difficult to achieve in this anatomical situation, especially due to the tension-stretch forces exerted by the tongue and the inferior lip. Moreover, in cases of significant atrophy, the mandible is poorly vascularized. The importance of the local soft tissue and bone vascularization has been mentioned by Kusiak et al. (1985), who noted the growth of host local soft tissues and bone vessels after bone grafting in rabbits. A deficiency of low-caliber terminal vessels, in patients with serious mandibular atrophy and frequent current tobacco use (Levin et al., 2004; Levin and Schwartz-Arad, 2005), could be expected to decrease graft revascularization and viability. Masticatory bone strains and torques (Champy and Lodde, 1977; Langenbach et al., 2006), and direct lingual and lower lip pressures on the symphysis area (Liu et al., 2008) may lead to graft micromovements and, consequently, to bone resorption. Finally, many patients put their non-adapted prosthodontic appliance back on prematurely, compressing and resorbing the bone graft.

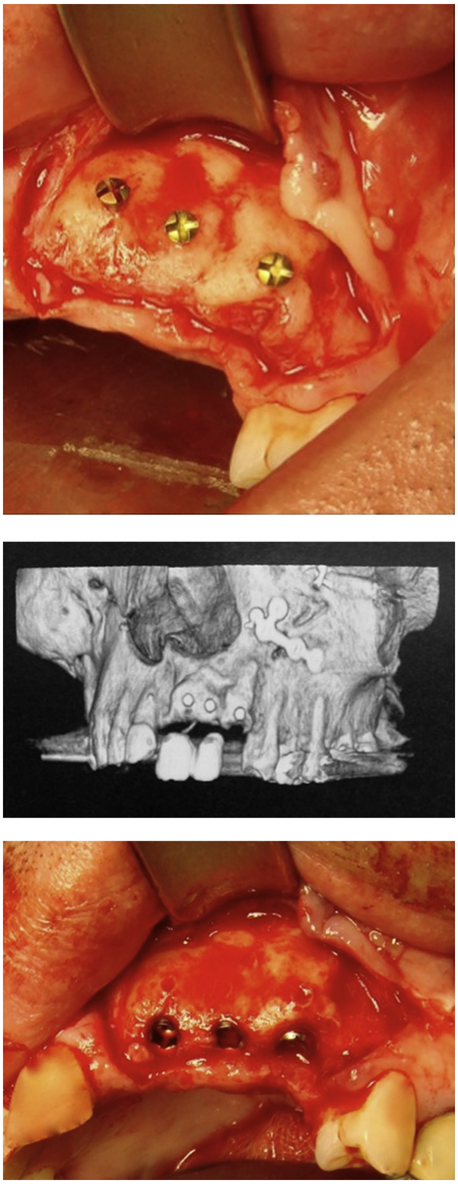

Fig. 9. Screw removal and implant placement. Parietal bone graft offers very good density and stability for endosseous implants after 6 months.

Fig. 10. Screw removal and implant placement. Parietal bone graft offers very good density and stability for endosseous implants after 6 months.

For the corpus, the percentage of secondary procedures was 11%, with the majority for graft exposure. This can be explained by the difficulty of securing the graft to the host bone, the anatomy of the area making tight closure of the mucosa difficult, and muscle movements compromising the suture line. When the graft is exposed, infection is systematic and leads to significant resorption. Finally, in this area, nerve lateralization may be a good option in certain situations, by providing a sufficient amount of bone for implant insertion (Tao et al., 2008).

At the maxillary floor, sinus graft procedures produce good results with low rates of secondary grafting procedures (1.8%). We explain the low rate of bone resorption, except in case of graft infection, by the protection of the graft from lingual pressure, the very limited masticatory maxillary bone's torques, and the large surface contact area between the graft and the host bone, inducing early revascularization and graft osseointegration. In the sinus, the graft receives blood supply from the sinus walls and floor. There is a single dimension to rebuild (the vertical dimension), and this situation is particularly favorable for rapid neovascularization of the grafted bone.

Clinically silent lesions of the maxillary sinus mucosa could explain the infection rate during the sinus lift procedure. No case of infection was reported when a Le Fort I technique was used. This may be because the sinus membrane is completely removed during this procedure and no contact remains between the mucosa and the bone graft. The infection rate during the sinus lift procedure led us to prefer autologous bone graft to biomaterial for the first procedure. Indeed, biomaterials, remaining foreign structures for a long time before resorption, have poor resistance against infections, especially for large grafting procedures (Hallman et al., 2002; Schimming and Schmelzeisen, 2004; Meyer et al., 2009). Systematically, we recommend prophylactic antibiotic treatment after the maxillary sinus grafting procedure, for a minimum of 3 weeks.

At the premaxilla, the secondary procedure rate was moderate (6.4%). No infection occurred in our series. The resorption at this site was sometimes high, especially when both vertical and sagittal reconstructions were required. This site has been recognized as the most complex area to rebuild in the maxilla, due to the frequent direct pressures from soft tissues (tongue and upper lip movements) and the difficulty of the framework technique (Jensen and Sindet-Pedersen, 1991; Tulasne, 1999; Iizuka et al., 2004; Ferri et al., 2008) (Fig. 10). Moreover, this area, challenging because of esthetic considerations, is particularly prone to the side effects of smoking (Nitzan et al., 2005).

5. Conclusion

To conclude, the parietal bone graft offers results at least as interesting as other techniques using autogenous bone in maxillofacial reconstruction. The harvesting technique is associated with a reduced morbidity in experienced hands, with no serious complications observed (Touzet et al., 2011). To improve the sampling procedure, we must pay attention to the reconstruction of the donor site (Denglehem et al., 2011) and to avoidance of tension on the scalp suture line.

The implant success rate, while showing slight variation according to the anatomical site, is high overall (95%) and comparable to that in the literature. A relatively high number of secondary procedures were observed, stemming from extensive alveolar bone resorption in patients, the need for large grafts, and the frequent presence of uncontrolled patient behaviors such as poor oral hygiene, smoking, and low treatment compliance.

Fretwurst et al. (2015) performed a long-term retrospective evaluation of the peri-implant bone level in onlay-grafted patients with iliac bone. Over a mean observation period of 69 months after implant surgery, the authors demonstrated relative stability of the peri-implant bone level. Duttenhoefer et al. (2015) performed a similar evaluation of long-term stability of bone level non-vascularized fibula grafted in edentulous patients, over a mean follow-up of 10 years. Such a study should be realized for maxillofacial reconstruction using parietal bone graft, even if the remarkable stability of this material is largely known.

Conflict of interest

The authors declared no conflicts of interest.

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