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Original Article

Assignment of autogenous bone grafts for reconstruction of the alveolar ridge before implant placement

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Abstract – Introduction: Autologous bone is considered to be the "gold standard" for the reconstruction of the reabsorbed alveolar ridges. For small defects, autologous bone samples can be harvested from intraoral donor sites. However, extraoral donor sites are the first choice for any extensive augmentation of the alveolar ridges. The resorption of the bone grafts depends on several factors, including the recipient sites, the donor sites, volume of the bone grafts and whether or not the patient smokes. The aim of this study was to investigate the rate of autologous bone graft resorption, 4 months after the surgical reconstruction, according to their sites of origin, parietal or ramus, according to the grafted site, mandible or maxilla and according to the surgical indications. **Patients and methods:** 22 patients had 51 reconstructions of alveolar ridges with ramic or parietal onlay bone grafts. The increase of bone volume was assessed with computed tomography, immediately after augmentation (V0) and 4 months after the procedure (V1), before the placement of dental implants. **Results:** The mean rate of bone resorption was 26% for the parietal bone grafts and 27% for the ramus bone grafts after 4 months (p: ns). This rate was 26% for maxillary grafts and 25% for mandibular grafts (p: ns). This rate varies from 22% to 33% according to the etiology of the bone defect but these variations are not significant and ultimately, this rate of bone resorption was unaffected by the gender of patients. **Conclusion:** Based on these findings, the resorption of onlay grafts doesn't seems to be affected by the recipient and donor sites nor by the etiology of the bone defects. Parietal and ramic bone grafts showed limited resorption rates for the pre-implant reconstruction of alveolar ridges.

Introduction

An autologous bone is currently recognized as the gold standard for alveolar bone reconstruction of the maxilla, mainly for implant purposes [1,2]. When a pre-implant bone-reconstruction is considered, the choice of the sampling site essentially depends on the size of the defect to be corrected. Intraoral specimens are reserved for mild to moderate bone defects (classes IV and V according to Cawood & Howell [3]) and extraoral specimens for moderate to severe defects (class VI [4]). Intraoral sampling sites include the mandibular symphysis, mandibular ramus, and maxillary tuberosity [5]. The most commonly used extraoral sample in pre-implant reconstruction is the parietal bone [6].

The resorption of autologous grafts is a derogatory factor which must be taken into consideration at the time of reconstruction [7]. This resorption is variable and depends on several criteria, including the sampling and recipient sites [6].

The main objective of this retrospective study was to quantify and compare the resorption of autologous grafts of ramic and parietal origin at 4 months postoperatively, *i.e.*, just before the placement of dental implants. The secondary objective was to determine the influence of factors, other than anatomical origin of the graft, such as sex and recipient site, on the rate of resorption.

Patients and methods

Study characteristics

This retrospective study was conducted between 2014 and 2017. Given the legislation in force at the time, no ethical authorization was necessary after consulting the institution's clinical research department. It included 51 autologous bone grafts in 22 consecutive patients, whose bone volumes were insufficient to allow the placement of dental implants from the outset. The inclusion criteria were as follows: patients with a bone defect localized to a minimum or generalized to an entire maxilla, those in whom the bone defect was vertical and/or

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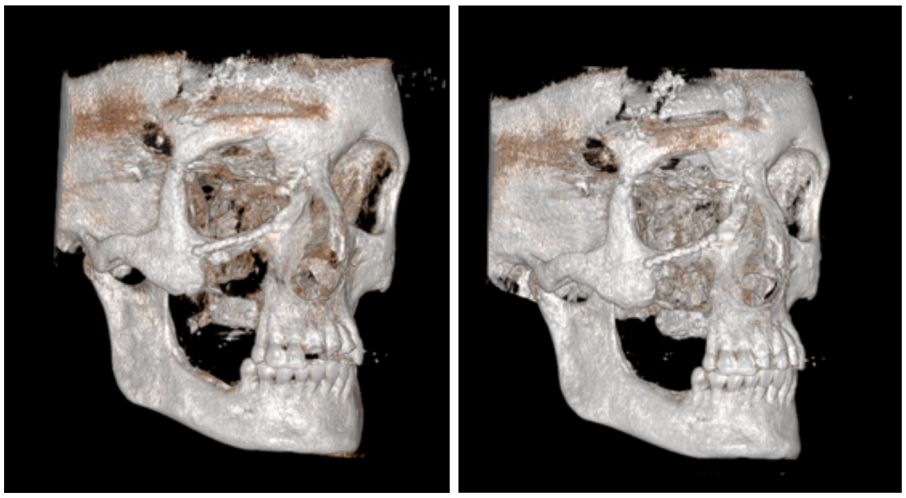

Fig. 1. 3D reconstruction of CBCT immediately after surgery at T0 (left) and after a healing period of 4 months (T1; right). In this case, the bone graft is on the upper right maxilla.

horizontal and maxillary and/or mandibular, those in whom the donor bone site was either the parietal (parietal bone) or ramus, and those in whom bone resorption was followed by dental extractions, dental agenesis, dento-alveolar trauma, or labio-maxillo-palatal clefts. The exclusion criteria were as follows: postoperative resorption of the graft >50% of its initial volume, which was then considered a failure of the bone augmentation technique; lack of adequate radiological control; and consumption of tobacco [8].

Surgical procedure

The two sampling sites were the mandibular ramus and parietal. The size and number of grafts removed depended on the size of the bone defect to be reconstructed. The grafts were stabilized by osteosynthesis screws.

Antibiotic therapy was routinely prescribed postoperatively [amoxicillin + clavulanic acid (Augmentin®); 1 g three times daily for 7 days].

Imaging

For each patient, cone-beam computed tomography (CBCT, ORTHOPHOS XG® Sirona, Bensheim, Germany) was performed immediately after the bone reconstruction surgery (T0) to verify proper adaptation of the bone graft to the recipient site. This examination was enabled to calculate the reconstructed bone volume reference at T0. Second CBCT was performed after 4 months of bone healing, just before the placement of dental implants (T1) (Fig. 1). This second examination enabled to calculate the residual reconstructed bone volume. CBCTs were performed on the same device, and patients were positioned in the cephalostat in an identical manner. The occlusion plane was parallel to the floor so that it could be easily reproduced.

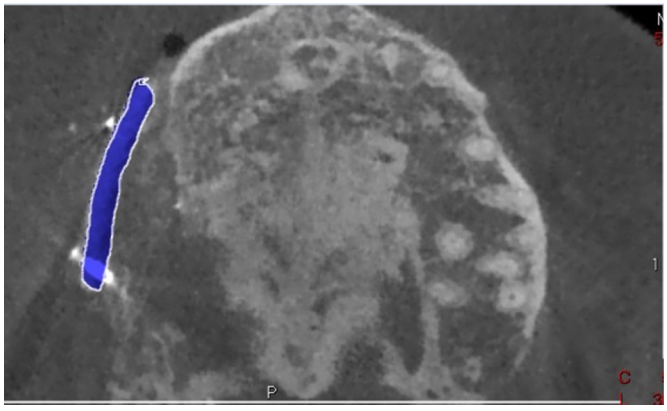

Fig. 2. Axial section of CBCT at T0 (same patient as in Fig. 1). The limits of the graft were delimited manually every millimeter and so to determine the volume of interest (blue).

Measurements

Measurements were performed manually using cross sections of CBCT. The contours of each graft were delimited every 1 mm of the section (Fig. 2); then, CARESTREAM® software was used to calculate the bone volume of the graft in cubic centimeters (Fig. 3).

The volume of the graft immediately after the procedure (at T0) was denoted as V0 and that after bone healing at 4 months (at T1) as V1. Bone graft resorption was expressed as percentage (%) according to the ratio V1/V0 (V0 = 100% by definition).

Statistical analysis

PRISM® software (GraphPad Software, La Jolla, California, USA) was used for statistical tests. The comparison of the

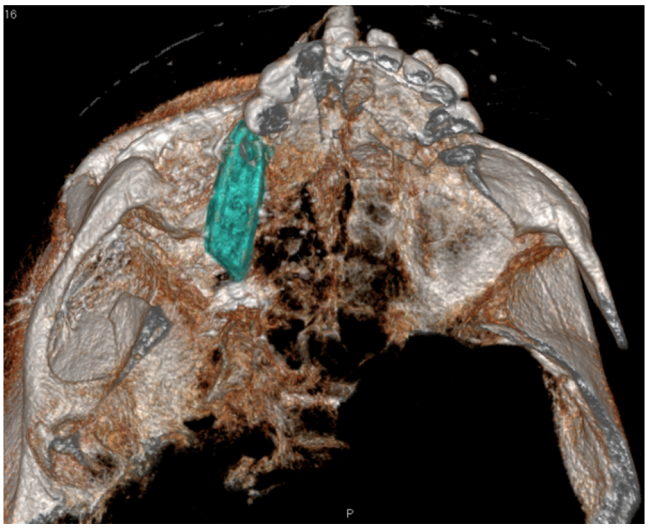

Fig. 3. Bone graft in the upper right (green area) on 3D reconstruction of CBCT (same patient as in Figs. 1 and 2).

resorption rates (expressed as percentage) was performed using a non-parametric Mann–Whitney test because they were unpaired values and did not follow a normal distribution.

The level of significance was set at $p < 0.05$.

Results

Out of 22 patients included in the study, 12 were female and 10 were male. The mean age was 42 years (range, 18–73). Out of 51 transplants, 40 were performed on the maxilla and 11 on the mandible. Eighteen were grafts of ramic origin and 33 of parietal origin. Information regarding the site of collection, recipient site, volumes of each T0 and T1 grafts, and bone resorption rate are summarized in Table 1.

The mean V0 of parietal grafts was 1.0 ± 0.97 cm^3 (range, 0.16–3.79 cm^3) and of ramus grafts was 0.43 ± 0.28 cm^3 (0.06–1.13 cm^3). The analysis of bone resorption rates at 4 months did not show a significant difference according to the anatomical origin of the autologous graft [parietal *versus* ramus: 25.94% (±12%) and 26.84% (±14%), respectively; $p = 0.80$; Fig. 4)], which did not show a significant difference between the resorption rates of maxillary and mandibular grafts with average resorption rates of 25.79% (±13%) and 25.52% (±12%), respectively ($p = 0.84$; Fig. 5). The rate of bone resorption at 4 months ranged from 22.32% (±13.74%) for bone defects caused by old dental extractions to 33.76% (±11.07%) for those secondary to cleft palates, with 24.28% (±10.55%) for those caused by trauma and 28.86% (±10.12%) for those secondary to dental agenesis. However, no significant differences were recorded between all these rates ($p = 0.09$; Fig. 6).

We also found no significant difference in bone resorption between males and females at 4 months, with the mean resorption rates of 25.41% (±12%) and 26.07% (±13%), respectively ($p = 0.77$; Fig. 7).

Discussion

Pre-implant bone reconstruction with an autologous bone graft is currently the most documented technique in the literature in terms of patient sample size, follow-up period, and study reliability [1,5,9–11]. However, the literature fails to compare the resorption rates between ramus *versus* parietal sites. However, this is fundamental information that would enable to estimate over-correction pre-operatively. To the best of our knowledge, this study, despite its limitations, is the most extensive in terms of the sample size.

According to the results recorded in our study, grafts taken from the ramus and parietal did not exhibit any significant differences in terms of postoperative resorption at 4 months. For both the ramus and parietal, the average rate of resorption was approximately 25%, regardless of the criteria taken into account. Therefore, at the time of reconstruction, it seems sensible to over-correct the alveolar defects in anticipation of this potential additional resorption.

Similar bone resorption rates have been reported in the literature. According to Gultekin *et al.*, bones of ramic origin showed absorption rate between 5% and 28% [15]. In a prospective study including 18 ramus grafts in 15 patients, Cordaro *et al.* reported the resorption rate between 23% and 42% after a healing period of 4 months [5].

In a study including 13 parietal grafts, Iizuka *et al.*, in 2004, showed a resorption rate of 16.2% after 6 months [9]. Smolka *et al.* reported a resorption rate of 19% after 1 year in a sample of 51 grafts [14]. Our study showed slightly higher resorption rates for parietal grafts. It is very interesting to note that according to the results recorded in our study, the etiology of the bone defect does not play any role in this rate of postoperative bone resorption, although a trend toward an increase in this resorption rate seems to be emerging in case of cleft palate correction. A small sample size in our study could explain this lack of significance. However, to the best of our knowledge, this is the first study comparing the resorption rate in several different etiologies of bone defects.

According to a literature review by Chiapasco *et al.*, in 2006, the factor that would most influence postoperative bone resorption is the anatomical origin of the bone graft [12]. Therefore, a graft of iliac origin resorbs more than a graft of cranial or intraoral origin. Misch *et al.*, in 1997, showed that bones of membranous origin (cranial bone) resorb less than those of endochondral origin (iliac bone) [13]. It should be noted that the ramus has a membranous embryological origin, similar to parietal, and this is one of the reasons that motivates the preferred use of these sampling sites in dental pre-implant bone reconstructive surgery. The architectural structure of the graft and in particular, the proportion of spongy bone compared with that of cortical bone, which is less permeable to revascularization, seems to be a factor that explains these differences in post-graft bone resorption rates

Table 1. Characteristics of the 51 autologous grafts: etiology of bone atrophy, donor site (ramus or calvaria), recipient site (maxillary or mandible), volume of the graft immediately after surgery (cm3), volume of the graft after a healing period of 4 month (cm3), lost volume after 4 months (cm3), percentage of bone resorption in 4 months.

Cas	Etiology of bone atrophy	Donor site	Recipient site	Volume of the initial graft (cm^3)	Volume of the graft at 4 month (cm^3)	Volume of the graft after a healing period of 4 month (cm^3)	Percentage of resorption at 4 months
1	Avulsion	Ramus	Maxilla	1,13	1,07	0,06	5,3
2	Avulsion	Calvaria	Maxilla	2,63	2,49	0,14	5,3
3	Avulsion	Calvaria	Maxilla	2,78	1,95	0,83	29,9
4	Avulsion	Ramus	Maxilla	1,09	0,99	0,10	9,2
5	Avulsion	Calvaria	Maxilla	0,43	0,26	0,17	39,5
6	Avulsion	Calvaria	Maxilla	0,26	0,14	0,12	46,1
7	Avulsion	Calvaria	Maxilla	0,71	0,48	0,23	32,4
8	Avulsion	Calvaria	Maxilla	0,55	0,39	0,16	29,1
9	Avulsion	Calvaria	Maxilla	0,70	0,51	0,19	27,1
10	Avulsion	Calvaria	Maxilla	3,79	2,99	0,80	21,1
11	Avulsion	Calvaria	Maxilla	3,78	2,89	0,89	23,5
12	Fente	Calvaria	Mandible	0,61	0,54	0,07	11,5
13	Fente	Calvaria	Mandible	0,86	0,51	0,35	40,7
14	Fente	Calvaria	Mandible	0,89	0,67	0,22	24,8
15	Fente	Calvaria	Mandible	0,84	0,45	0,39	46,5
16	Fente	Calvaria	Maxilla	0,69	0,46	0,23	33,4
17	Fente	Calvaria	Maxilla	0,75	0,54	0,21	28
18	Fente	Calvaria	Maxilla	0,56	0,31	0,25	44,7
19	Fente	Calvaria	Maxilla	0,68	0,42	0,26	38,3
20	Traumatisme	Calvaria	Maxilla	0,88	0,59	0,29	33
21	Traumatisme	Calvaria	Maxilla	0,51	0,38	0,13	25,5
22	Traumatisme	Calvaria	Maxilla	0,39	0,29	0,10	25,7
23	Traumatisme	Calvaria	Maxilla	0,35	0,20	0,15	42,9
24	Traumatisme	Calvaria	Maxilla	2,25	1,81	0,44	19,6
25	Avulsion	Calvaria	Maxilla	0,38	0,38	0	0
26	Avulsion	Calvaria	Maxilla	0,38	0,21	0,17	44,8
27	Avulsion	Calvaria	Maxilla	0,16	0,12	0,04	25
28	Avulsion	Calvaria	Maxilla	0,94	0,88	0,06	6,4
29	Avulsion	Ramus	Maxilla	0,50	0,31	0,19	38
30	Avulsion	Ramus	Maxilla	0,39	0,25	0,14	35,9
31	Agénésies	Ramus	Maxilla	0,31	0,26	0,05	16,2
32	Agénésies	Ramus	Maxilla	0,26	0,17	0,09	34,6
33	Fente	Ramus	Maxilla	0,16	0,11	0,05	31,2
34	Avulsions	Ramus	Maxilla	0,76	0,74	0,02	2,6
35	Avulsions	Ramus	Maxilla	0,49	0,32	0,17	34,7
36	Avulsions	Ramus	Maxilla	0,24	0,15	0,09	37,5
37	Avulsions	Ramus	Maxilla	0,08	0,05	0,03	25
38	Avulsions	Ramus	Maxilla	0,37	0,34	0,03	8,1
39	Avulsions	Ramus	Maxilla	0,48	0,42	0,06	12,5
40	Fente	Ramus	Maxilla	0,36	0,19	0,17	47,3
41	Traumatisme	Calvaria	Maxilla	0,97	0,79	0,18	18,6
42	Traumastisme	Calvaria	Maxilla	0,28	0,26	0,02	7,2
43	Avulsions	Calvaria	Mandible	0,54	0,42	0,12	22,3

Table1. (continued).

Cas	Etiology of bone atrophy	Donor site	Recipient site	Volume of the initial graft (cm^3)	Volume of the graft at 4 month (cm^3)	Volume of the graft after a healing period of 4 month (cm^3)	Percentage of resorption at 4 months
44	Avulsions	Calvaria	Mandible	0,48	0,38	0,10	20,9
45	Avulsions	Calvaria	Mandible	0,46	0,40	0,06	9,1
46	Avulsions	Calvaria	Mandible	0,44	0,39	0,05	11,4
47	Agénésies	Ramus	Mandible	0,42	0,25	0,17	40,5
48	Agénésies	Ramus	Mandible	0,42	0,27	0,15	20,6
49	Agénésies	Ramus	Mandible	0,34	0,23	0,11	32,4
50	Traumatisme	Calvaria	Maxilla	2,17	1,70	0,47	21,7
51	Fente	Ramus	Maxilla	0,16	0,12	0,04	25

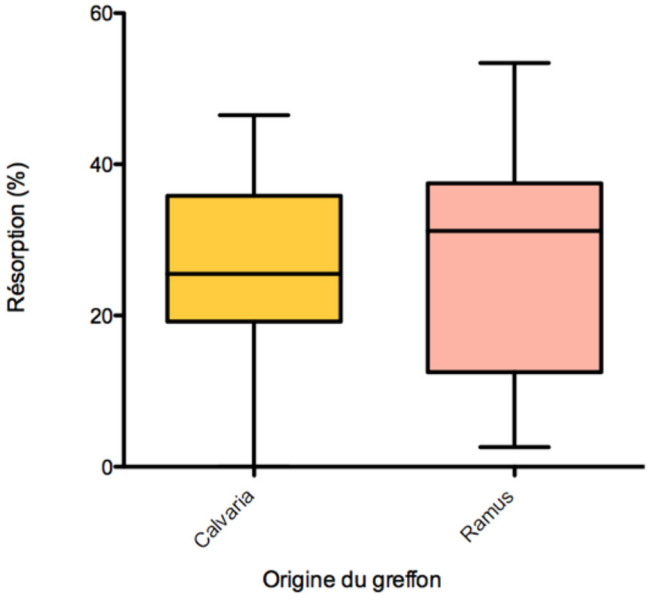

Fig. 4. Graph comparing the bone resorption rates (%) of the grafts according to the site of sampling (parietal and ramus) after a healing period of 4 months ($p = 0.80$).

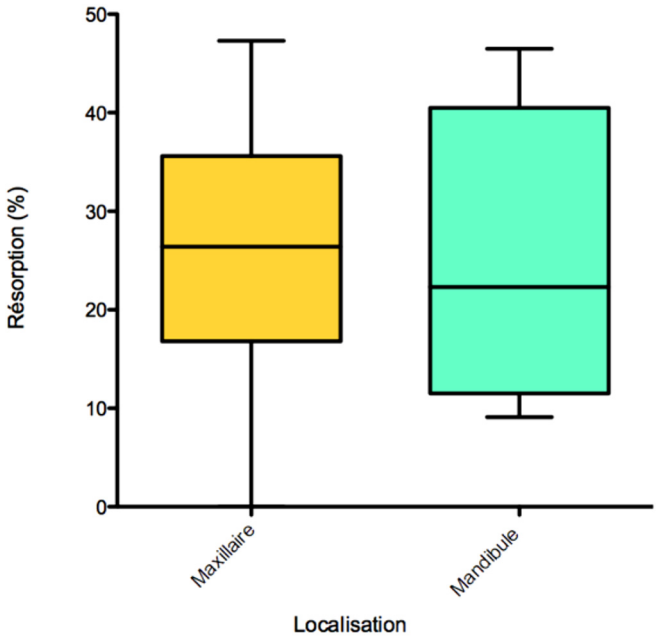

Fig. 5. Graph comparing the bone resorption rates (%) of the grafts according to the grafted site (maxilla or mandible) after a healing period of 4 months ($p = 0.84$).

[12,13]. To our knowledge, no study has shown architectural differences between ramus and parietal grafts as predictors of the post-graft bone resorption rate.

A healing time of 4 months is demonstrated to be sufficient for a bone of membranous origin (ramus and parietal), whereas a period of at least 6 months is necessary for a bone of endochondral origin (iliac) [2]. Therefore, the use of grafts with a bone of iliac origin has been decreasing in the field of pre-implant oral bone reconstruction. The results of our study showed sufficient bone volumes and a dense and homogeneous bone structure from the control images after 4 months of healing with grafts of membranous origin.

Chappuis *et al.*, in 2017, showed that the recipient site would not have a significant influence on the post-transplant bone resorption rate [11]. This is in agreement with our study.

The data generated by our study are interesting but must be interpreted with caution. Indeed, our study had several limitations: The lack of reliability with a small sample of patients but also significant variations around the mean values was a limitation. In fact, volume analysis showed resorption rate differences both for the ramus and parietal groups. Therefore, larger number of patients should be recruited. In addition, this study was based on the clinical experience of a

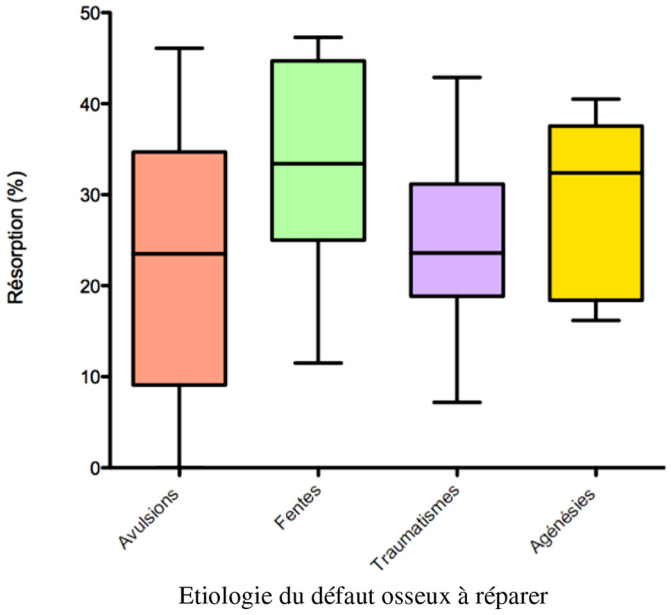

Fig. 6. Graph comparing the bone resorption rates (%) of the grafts according to the indication of the bone graft after a healing period of 4 months ($p = 0.09$).

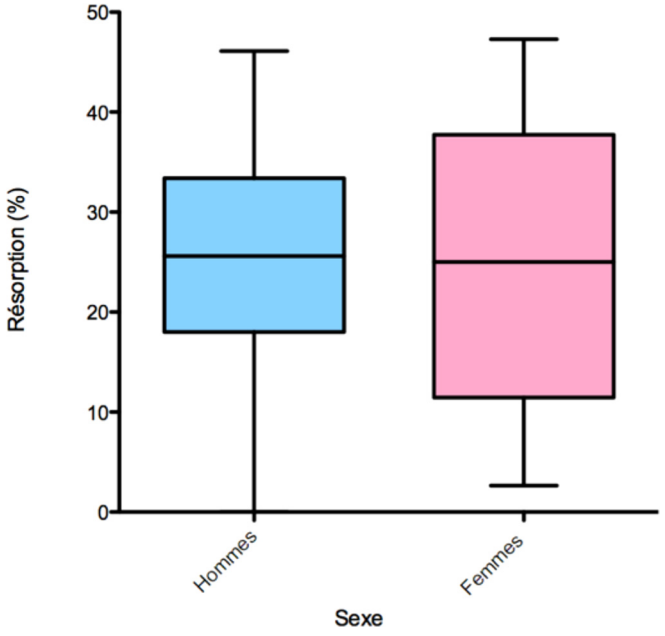

Fig. 7. Graph comparing the bone resorption rates (%) of the grafts according to the sex of the patient after a healing period of 4 months ($p = 0.77$).

single surgical team; hence, the study results cannot be generalized. To overcome this bias, it would be appropriate to perform such a study at multiple centers.

Conclusion

Within the limits of this study, ramus and parietal grafts have sufficiently low and comparable resorption rates to allow for reliable placement of dental implants. Only the quantity of available material makes one sampling site preferable over another.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the publication of this article.

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