Subantral bone grafts, a comparative study of the degree of resorption of alloplastic versus autologous grafts

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Abstract
The placement of dental implants in the posterior region of the maxilla may pose some difficulties caused by the quality and particularly, the quantity of the subantral bone reserve, which are overcome by subantral bone augmentation. The current study performs a comparative evaluation of the quality and especially, of the stability of alloplastic and autologous materials used for subantral bone augmentation. This study included 21 patients who underwent subantral bone augmentation with alloplastic and autologous material. The patients were followed-up over a 24-month period after bone augmentation, during which the osseointegration rate of dental implants and the stability of subantral grafts were evaluated. The rate of failure of dental implants placed in autologous material grafts was 1.89% (0.036±9.398), while the rate of failure of those placed in alloplastic material was 7.69% (1.960±19.194). Bone resorption was higher within 12 months of dental implant placement both for the alloplastic material (9.87±3.76%) and the autologous material (18.87±3.25%), while 12–24 months after bone augmentation it diminished. The implants placed in the autologous bone grafts had a lower rate of failure compared to those placed in the alloplastic material grafts; in contrast, alloplastic material had a lower resorption rate compared to autologous material.

Keywords: bone grafts, sinus lift, dental implants.

Introduction
The objective of reconstructive oral surgery is the functional and esthetic rehabilitation of patients in a way that is as close as possible or identical to their natural state [1]. The reconstruction of edentulous areas using dental implants is a unique modality by which this objective can be achieved [1]. The placement of endosseous implants in the posterior maxillary may raise a number of problems that are mainly related to the presence of the maxillary sinus at this level, but also to post-extraction bone atrophy [2] or poor bone quality [3]. The presence of prolonged edentation in the posterior region of the maxilla leads to a marked diminution of alveolar bone due to post-extraction bone resorption and maxillary sinus pneumatization [4].

The main alternative for the reconstruction of bone defects in the posterior region of the maxilla is sinus lift [5]. The aim of this procedure is to create a bone volume in the posterior maxillary region to allow the placement of endosseous dental implants [6]. Tatum proposed the placement of dental implants in sites with bone grafts used for the elevation of the maxillary sinus floor by lateral approach [4]. This procedure is widely used and recommended [1, 2, 7]. Four types of bone materials can be used as grafts for sinus floor lift: autogenous bone, allogeneic bone, xenogeneic bone, and alloplastic bone [1, 2]. Regardless of the type of material used as a graft, an 88–98% integration of dental implants 6–12 months after their placement was seen [8, 9]. On the other hand, the quality and stability of the augmentation material in which the dental implants are placed remain a controversial subject. Autologous bone is considered to have optimal osteoinductive properties [1, 10–12], while xenogeneic bone is considered to be more resorption resistant [1, 13]. Other studies recommend alloplastic materials as an alternative for sinus floor grafting [9, 14].

Studies performed so far describe a number of limitations that may affect the results obtained. A major limitation is the fact that the evolution of subantral grafts is most frequently followed-up for only approximately 12 months after their placement [11–13]. Another limitation is the fact that the augmentation materials that are compared are not used in the same individual and thus, the evolution of the grafts can be influenced by the metabolic particularities of each individual and not but their quality [1, 2, 11, 12, 14].

The aim of this study is to assess the stability of sinus grafts in which dental implants were placed. We wish to overcome the previously mentioned limitations by monitoring the stability of bone grafts 24 months after dental implant placement and by using alloplastic and autologous grafts in the same individual.

Patients and Methods
This study included 27 patients who came to the Clinic of Oral and Maxillofacial Surgery, Cluj-Napoca, Romania, in the period January 2007–December 2011, for bilateral sinus lift. The study protocol was approved by the Ethics Committee of the “Iuliu Hațieganu” University of Medicine and Pharmacy, Cluj-Napoca, on June 11, 2014, approval No. 222. All the patients included in the study signed an informed consent by which they agreed to participate in scientific studies.

The study inclusion criteria were: need for bilateral
sinus lift, absence of sinus pathology, absence of chronic systemic diseases, postoperative follow-up for at least 24 months after bone augmentation, patient signing the informed consent.

Study exclusion criteria: absence of postoperative follow-up, intraoperative sinus membrane perforation, postoperative complications, failure of treatment with dental implants after their prosthetic loading.

Of all 27 patients, 21 cases met the study inclusion criteria.

Surgery

Surgery was carried out under general anesthesia with nasotracheal intubation and bilateral sinus lift was performed. In a sinus cavity, subantral augmentation was performed with PerioGlass particles (NovaBone products LLC) (Figure 1), and in the contralateral sinus, it was performed with autologous cortical and cancellous bone (Figure 2) obtained from the right anterior-superior iliac crest (Figure 3), prepared using a manual bone mill. All patients received antibiotics and anti-inflammatory drugs postoperatively, both after bone grafting and dental implant placement.

At six postoperative months, dental implants were placed. The sutures were removed 10 days after bone augmentation and seven days after dental implant placement. In all patients, the two-stage dental implant technique was used. Six months after the placement of dental implants, their functional loading was performed. Bone augmentation, dental implant placement and prosthetic loading were carried out by the same operative team.

Imaging evaluation

Imaging evaluation was conducted by a different team, according to a protocol similar to that presented by Peng et al. [2]. Four days after surgery, panoramic evaluation at a 1/1 scale was performed. The site for the placement of dental implants was established. At this level, a perpendicular line between the highest cranial point of the subantral graft evidenced by imaging and the alveolar ridge was drawn (Figure 4). This perpendicular was measured with 0.1 mm accuracy. The bone height thus obtained was considered as a reference for the bone height around each individual implant. Right after dental implant placement (six months after bone augmentation), a new panoramic X-ray was taken. On this X-ray, the bone distance between the highest cranial point of the bone graft, perpendicular to the caudal limit of the dental implant, was measured. This imaging evaluation was repeated prior to the intraoral exposure of dental implants (12 months after bone augmentation) and 24 months after bone augmentation (12 months after the functional loading of bone augmentation). The measurement of the bone level is illustrated in Figure 4.

The rate of bone resorption (BR) was calculated with the formula: (initial value – obtained value)/initial value × 100 [2]. This was calculated six months after bone augmentation (BR1), 12 months after bone augmentation (BR2) and 24 months after bone augmentation (BR3).

Subsequently, the rate of bone resorption after implant loading (BRIL) was also calculated: (value at the time of intraoral exposure – value at 12 months from intraoral exposure)/value at the time of exposure × 100. Time of intraoral exposure = 12 months after bone augmentation and implant loading.

Statistical analysis

The variables were summarized as counts and percentages with associated 95% confidence intervals (CI) provided in square brackets along the manuscript [15, 16] for quantitative variables. Quantitative variables were summarized as mean ± standard deviation whenever data proved to be normally distributed (according to the Anderson–Darling test); otherwise, median and interquartile range were provided (interquartile range is in round brackets along the manuscript). Comparisons between the alloplastic group and the autologous group were done with the Z-test for proportions, the paired t-test for normally distributed paired data, the Wilcoxon test for non-normally paired distributed data, and the Student’s t-test for independent samples (e.g., genders). Statistical analysis was conducted at a significance level of 5% with Statistica software (ver. 8).

Results

Twenty-one subjects were included in the study, 11 women and 10 men. The age of the subjects ranged from 46 to 68 years, men (61.00±14.44 years) being significantly older than women (53.55±31.07 years; t-statistics = -3.54, p=0.0022). Although female patients were statis-
bone resorption at six months (BR1) was 7.40±1.84 tenths of a millimeter, representing 0.74 mm. Compared to this, the relative percentage value expresses the degree of bone resorption in the first six months after bone augmentation (BR1), it can be seen that the higher resorption tendency of the autologous material. The value of the augmentation material used for bone augmentation, proves the fact that both material types yield good clinical results. As shown by statistical data analysis, the difference of dental implant osseointegration rate higher than 90%, regardless of the type of material used for bone augmentation, proves the fact that material resorbed in the 12–24 month period represents 0.74 mm. In the case of alloplastic bone augmentation, bone resorption at six months (BR1) was only 3.66±1.77 tenths of a millimeter, i.e., 0.366 mm. This bone resorption difference suggests more intense bone remodeling and osseointegration processes in the case of the autologous group compared to the alloplastic group. Relative bone resorption defined as the difference between baseline and six months relative to the baseline value, expressed as percentage, abbreviated as BR1 (%), proved significantly different in the autologous group compared to the alloplastic group (Figure 5), with a median value of 6.90% in the autologous group and a median of 3.45% in the alloplastic group. The relative percentage value expresses the degree of bone resorption of the two material types at population level.

A total of 53 dental implants were placed in autologous bone grafts and 52 dental implants were placed in alloplastic bone grafts, each subject having between two and three implants placed in each type of graft. One dental implant placed in an autologous graft was not integrated [1.89% (0.036±9.398)], while four dental implants placed in alloplastic grafts were not integrated [7.69% (1.960±19.194)]. No significant differences were observed when the percentage of non-integrated implants was compared between implants placed in autologous and alloplastic grafts (Z-statistic = -1.3953, p=0.1629). The implant osseointegration rate higher than 90%, regardless of the type of material used for bone augmentation, proves the fact that both material types yield good clinical results. As shown by statistical data analysis, the difference of dental implant osseointegration rate between the two types of material is not statistically significant. The presence of a lower rejection rate of the bone material placed in the autologous bone material (less than 2%) can be explained by the fact that bone healing and osseointegration processes are better in the case of autologous bone used as an augmentation material, which is more easily accepted and integrated in the bone metabolism of the recipient site.

The bone resorption rate six months after bone augmentation evidenced a higher value for autologous bone compared to alloplastic material. Thus, Table 1 shows the mean resorption values of the augmentation material in this time period by comparing the BR1 value in the autologous group to the BR1 value in the alloplastic group.

Table 1 – Summary of bone resorption and comparisons relative to baseline

<table>
<thead>
<tr>
<th>BR / BRIL</th>
<th>Mean; StDev</th>
<th>Median (Q1–Q3)</th>
<th>t-Statistics (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Autologous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BR1*</td>
<td>7.40±1.84</td>
<td>6.90 (6.61–8.63)</td>
<td>n.a.</td>
</tr>
<tr>
<td>BR2</td>
<td>18.87±3.25</td>
<td>19.05 (16.67–20.82)</td>
<td>-23.19 (&lt;0.0001)²</td>
</tr>
<tr>
<td>BR3</td>
<td>25.39±4.56</td>
<td>25.74 (21.88–29.13)</td>
<td>-28.56 (&lt;0.0001)²</td>
</tr>
<tr>
<td>BRIL*</td>
<td>8.05±4.00</td>
<td>8.33 (4.26–11.11)</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>Alloplastic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BR1²</td>
<td>3.66±1.77</td>
<td>3.45 (3.31–3.57)</td>
<td>n.a.</td>
</tr>
<tr>
<td>BR2²</td>
<td>9.87±3.76</td>
<td>10.00 (7.08–10.71)</td>
<td>6.03 (&lt;0.0001)²</td>
</tr>
<tr>
<td>BR3²</td>
<td>15.49±4.43</td>
<td>15.50 (11.71–17.86)</td>
<td>60.3 (&lt;0.0001)²</td>
</tr>
<tr>
<td>BRIL²</td>
<td>6.17±2.69</td>
<td>6.90 (3.8–7.69)</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

BR: Bone resorption; BRIL: Bone resorption after implant loading; M: Mean; StDev: Standard deviation; Q1: 1st quartile; Q3: 3rd quartile; *Normally distributed data (Anderson–Darling test); ²Non-normally distributed data; Student’s t-test; Wilcoxon test; n.a.: Not available; 1: Baseline vs. six months; 2: Baseline vs. 12 months; 3: Baseline vs. 24 months.

In the case of autologous bone augmentation, the mean bone resorption at six months (BR1*) was 7.40±1.84 tenths of a millimeter, representing 0.74 mm. Compared to this, in the case of alloplastic bone augmentation, bone resorption at six months (BR1²) was only 3.66±1.77 tenths of a millimeter, i.e., 0.366 mm. This bone resorption difference suggests more intense bone remodeling and osseointegration processes in the case of the autologous group compared to the alloplastic group. Relative bone resorption defined as the difference between baseline and six months relative to the baseline value, expressed as percentage, abbreviated as BR1 (%), proved significantly different in the autologous group compared to the alloplastic group (Figure 5), with a median value of 6.90% in the autologous group and a median of 3.45% in the alloplastic group. The relative percentage value expresses the degree of bone resorption of the two material types at population level.

At 12 months from bone augmentation, the maintenance and even an increase of autologous bone resorption (BR2) can be seen. A comparison of the degree of bone resorption at 12 months after bone augmentation shows a two times higher value of autologous bone resorption compared to the alloplastic material value. The mean resorption value expressed in tenths of a millimeter can be analyzed in Table 1. At 12 months after bone augmentation, the bone resorption difference between the two material categories was statistically significant (p<0.0001). The mean value of bone resorption expressed as percentage associated to the values of 12 months relative to baseline [BR2 (%)] was 14.38% for the autologous group and 5.85% for the alloplastic group. This result shows a significantly lower value in the alloplastic group compared to the autologous group (Figure 6). This increased difference between the mean percentage values of bone resorption supports the hypothesis that autologous bone has a significantly higher resorption tendency compared to alloplastic material at population level; this resorption tendency is almost three times higher in mean percentage values. Another aspect that should be noted is that this bone resorption rate includes bone resorption after the placement of the dental implants, without them being functionally loaded.

This difference could also be seen 24 months after bone augmentation. The mean resorption rates of the augmentation material at 24 months (BR3) after bone augmentation are shown in Table 1 both for the autologous material and the alloplastic material and confirm the higher resorption tendency of the autologous material. Although at first glance the resorption value of the two bone augmentation materials seems increased, it should not be overlooked that this resorption includes the resorption present both in the first six months after bone augmentation (BR1) and in the first six months after implant placement (BR2). The mean value of bone resorption expressed as percentage associated to the values of 24 months relative to baseline [BR3 (%)] was 20.43% for the autologous group and 11.06% for the alloplastic group. This result is similar to the results obtained for BR2 (%), showing a significantly lower mean in the alloplastic group compared to the autologous group (Figure 7). These percentage values at 24 months represent the mean value of the resorbed augmentation material in the population. The value of the augmentation material strictly resorbed in the 12–24 month period represents in fact the resorption following the functional loading of the osseointegrated dental implants (BRIL). Thus, by comparing bone resorption at one year from functional implant loading for autologous bone (BRIL) and bone resorption in the first six months after bone augmentation with this type of material (BR1), it can be seen that the...
two values are very close (Table 1), which suggests a slowing of bone resorption, possibly on the background of increased bone maturation. On the other hand, the same comparison performed for the alloplastic material evidences a greater difference between the two values (Table 1), which suggests a slower maturation of bone obtained using this type of material. Seventy-five percent of the cases showed a relative bone resorption value after implant loading lower than or equal to 11.11% in the autologous group and 7.69% in the alloplastic group. The median value of BRIL (%) proved to be significantly higher in the autologous group compared to the alloplastic group (Figure 8). Although the bone resorption percentage in the autologous group remained significantly higher than in the alloplastic group, the difference between the two compared values tended to decrease, and the volume stability of the grafts in the two studied groups tended to be similar after functional implant loading.

Bone resorption variables were evaluated for each sex both for the alloplastic and the autologous material. The patient’s gender did not influence the comparative difference between the two types of material. No significant differences were identified when the comparison was conducted between the two genders (Table 2).

Table 2 – Bone resorption and bone resorption after implant loading: comparisons between genders

<table>
<thead>
<tr>
<th>BRI / BRIL</th>
<th>Females</th>
<th>Males</th>
<th>t-Statistics (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autologous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRI¹</td>
<td>6.92±3.33</td>
<td>7.32±2.02</td>
<td>-0.51 (0.6134)</td>
</tr>
<tr>
<td>BR²</td>
<td>17.70±4.33</td>
<td>19.75±3.47</td>
<td>-1.87 (0.0680)</td>
</tr>
<tr>
<td>BR³</td>
<td>24.76±4.96</td>
<td>25.97±4.51</td>
<td>-0.91 (0.3654)</td>
</tr>
<tr>
<td>BRIL⁴</td>
<td>8.55±4.42</td>
<td>7.77±3.47</td>
<td>0.71 (0.4835)</td>
</tr>
</tbody>
</table>
The objectives of this study were achieved. Thus, in a relevant group of cases, the evolution of alloplastic and autologous sinus grafts placed in the same patient could be analyzed. The gender distribution of the patients included in the study was relatively equal, which indicates the fact that the need for bilateral sinus lift was equally frequent in female and male patients. The fact that male patients were older than female patients might indicate the fact that they lost posterior maxillary teeth later in life. This cannot be objectively demonstrated because of the small number of subjects included in the study, but also because male patients might have neglected for a longer time period the restoration of the lost teeth. The analysis of the age of both female and male patients shows that these were within the age range reported by other similar studies [3, 17].

The presented data evidence a low failure rate of the osseointegration of the dental implants placed in the bone augmentation area, regardless of the type of material used for sinus floor augmentation. The data are similar to those published by other authors who evidence a 95% success rate of dental implants [3, 17]. It should be mentioned that literature studies provide different values of the success rate of therapy with dental implants depending on the time of their evaluation: higher rates of successful osseointegration are reported prior to functional loading; while after implant loading, the rate of success decreases [3, 17, 18]. The increase of the rate of failure of dental implant treatment after functional loading can be due to many causes, some of which are independent of the medical treatment used and dependent on the patient. For this reason and because the aim of this study was to assess the stability of bone grafts, the quality of osseointegration after implant loading was not analyzed. This is why one of the exclusion criteria was the failure of dental implants after their functional loading.

The implants placed in the alloplastic augmentation material had a higher failure rate compared to those placed in the autologous augmentation material. Although the difference between the two rates of failure was not statistically significant, alloplastic implants had a four times higher rate of failure than autologous implants. This difference of implant osseointegration might be due to the difference in the quality of the receptor bed of dental implants. Autologous bone graft is considered to be qualitatively superior to other types of grafts, having the optimal quality of stimulating osteoinductive processes [1]. In a previous study that used the same type of alloplastic material for subantral augmentation, it was shown that six months after bone augmentation, the newly formed bone represented 35% of the total analyzed mass [19]. Taking into consideration the above-mentioned, it is very likely that in the case of implants placed in alloplastic augmentation material, bone apposition at the implant–bone interface is slower, which is why their rate of failure is higher compared to that of implants placed in autologous material.

The measurement of bone resorption using panoramic X-rays at a 1/1 scale is one of the most widely used methods for assessing postoperative evolution in current practice. This method has a number of disadvantages resulting from the incapacity to measure the bone volume obtained because it is a two-dimensional method, and from lower image accuracy. The optimal imaging method for the evaluation of the maxillary sinus is cone beam computed tomography (CBCT), but previous studies show a concordance between CBCT evaluation and panoramic evaluation [20]. In addition, the great majority of the patients, particularly if they do not have subjective postoperative complaints, are reluctant to undergo serial CBCTs. This is why panoramic radiography, which despite some inconveniences has a major importance in current medical practice, was chosen for the assessment of bone resorption.

The evaluation of bone resorption shows the fact that the most active period is represented by the first 12 months after subantral augmentation, which is evidenced by other studies [1, 2, 21]. This rate of resorption seems to be due to the fact that within 12 months of augmentation material placement, the most important bone apposition and bone remodeling processes occur [14, 19]. The fact that in the first 12 months after bone augmentation there is an intense bone resorption and remodeling process is also confirmed by studies evaluating the residual bone volume by three-dimensional methods using CBCT [22]. Similarly to the current study, these studies evidence the fact that autologous augmentation material has a significantly higher resorption rate (45.7±18.6% of the volume) compared to alloplastic material (38.3±16.6%) [22]. After this period, a reduction in the rate of resorption of the augmentation material can be seen, which is concomitant with the functional loading of dental implants in the case of this study. Although other authors report a diminution of the bone resorption rate after the first 12 months from bone augmentation, they do not correlate this resorption rate with the functional loading of dental implants [1, 2, 21]. We consider that there is a direct relationship between the functional stimulation of newly formed bone and the diminution of bone resorption, which is demonstrated statistically.

Although autologous grafts are considered by many authors to be superior to alloplastic grafts [11, 12], in terms of stability in time, alloplastic grafts proved to be superior. It is true that the rate of implant integration in

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<td>BR1</td>
<td>3.45</td>
</tr>
<tr>
<td>BR2</td>
<td>9.95±4.67</td>
</tr>
<tr>
<td>BR3</td>
<td>15.64±4.90</td>
</tr>
<tr>
<td>BRIL</td>
<td>5.60</td>
</tr>
</tbody>
</table>

M: Mean; StDev: Standard deviation; Q1: 1st quartile; Q3: 3rd quartile; n: No. of cases; BR: Bone resorption; BRIL: Bone resorption after implant loading; *Normally distributed data (Anderson–Darling test); Non-normally distributed data.

Discussion

The objectives of this study were achieved. Thus, in a relevant group of cases, the evolution of alloplastic and autologous sinus grafts placed in the same patient could be analyzed. The gender distribution of the patients included in the study was relatively equal, which indicates the fact that the need for bilateral sinus lift was equally frequent in female and male patients. The fact that male patients were older than female patients might indicate the fact that they lost posterior maxillary teeth later in life. This cannot be objectively demonstrated because of the small number of subjects included in the study, but also because male patients might have neglected for a longer time period the restoration of the lost teeth. The analysis of the age of both female and male patients shows that these were within the age range reported by other similar studies [3, 17].

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autologous grafts was higher, but there was no statistically significant difference between the two materials, which is confirmed by other studies [1, 2, 17, 18]. The stability in time of alloplastic grafts seems to indicate them as an optimal bone augmentation material, which allows to obtain a subantral bone volume that is stable in time. It remains to be determined whether and how the bone amount left at subantral level influences the evolution of dental implants.

Literature studies have compared the stability in time of grafts obtained from mixed autologous and alloplastic material compared to autologous grafts [2]. Other authors have compared the stability of xenograft augmentation to that of mixed xenograft and autologous bone graft augmentation [23]. These studies suggest that a mixture of autologous bone and xenograft or alloplastic material results in a higher success rate of dental implant therapy compared to autologous bone or xenograft alone, and the graft thus obtained has a volume that is more stable in time [2, 23]. Another category of authors tend to completely eliminate bone grafts and use the bone volume obtained only by sinus membrane elevation, without performing subantral bone augmentation. Thus, following a careful analysis of the literature, Pérez-Martínez et al. found an implant success rate after such bone augmentation procedures ranging between 94% and 100%, with a mean subantral bone height value of 3.43±0.09 mm [24]. We consider that the results of these studies are preliminary and further investigations are required.

Conclusions

Subantral augmentation with autologous bone leads to a higher degree of osseointegration of the dental implants placed in this material compared to those placed in alloplastic material, but without a statistically significant difference. However, alloplastic grafts have a lower rate of resorption compared to autologous grafts. Subantral bone resorption is more accelerated in the first year after the sinus lift procedure, and is slower during the second year after subantral bone augmentation.

Conflict of interests

The authors declare that they have no conflict of interests.

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