Sliding Genioplasty Using Fresh-Frozen Bone Allografts

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Objective: To present our experience in the use of fresh-frozen human bone allograft as an interpositional grafting material for sliding genioplasty to correct chin deformities.

Methods: Ten patients underwent sliding genioplasty using morcellized and corticospongious fresh-frozen human bone. Four patients underwent orthognathic surgery associated with genioplasty. Six patient underwent genioplasty associated with rhinoplasty. Panorex, lateral, and frontal cephalogram and computed tomographic scans have been performed for each case preoperatively and 12 months after surgery. One patient subsequently asked for plate removal, and with his consent, a bone biopsy specimen was obtained during the operation.

Results: Stable aesthetic and functional results were observed in all cases. No infections occurred, and no bone resorption has been clinically or radiologically observed.

Conclusion: The use of fresh-frozen bone allograft reduces patient morbidity and operative time, providing a stable and excellent aesthetic result.


The chin is one of the most prominent facial structures, and maxillofacial deformities are commonly associated with the chin area. Appropriate size, shape, and position of the chin can enhance the global facial harmony and symmetry. Thus, surgical correction of chin deformities is often required to improve harmony of the face.1

Two principal methods, alloplastic implantation and sliding genioplasty, are available for chin augmentation. Both techniques achieved excellent results. Sliding genioplasty is more commonly used by maxillofacial surgeons because it allows to correct bone abnormalities in all 3 dimensions, therefore representing a more flexible technique. This procedure is generally preferred in malocclusion associated with chin retrusion but is also indicated in association with rhinoplasty.2,3

The use of interpositional bone grafts proved to offer several advantages owing to their mechanical and biological behavior. Interpositional bone grafts provide a stable mechanical structure that decreases vertical height relapse, acts like a matrix for ossification,4 and prevents soft-tissue herniation into the osteotomy site. Together, these factors help to avoid the formation of a deep angular labiomental fold and to improve osseointegration and stabilization of the sliding segment.8

Various autologous, heterologous, and alloplastic interpositional grafts have been described as grafting interpositional materials in cases of mandibular advancement, maxillary Le Fort I osteotomy, and chin osteotomies.9 The main types of graft materials are autogenous bone grafts,1 freeze-dried bone,10 alloplastic material (Proplast; Vitek Inc) blocks,11 solid block of hydroxyapatite, and porous block of hydroxyapatite.12

The autogenous bone grafts represent the “gold standard” because of their osteogenic potential, osteoconductivity, and osteoinduction,13 but the use of autogenous grafts implies the availability of a donor site, thus increasing morbidity and operative time.14,15 Alloplastic materials require a long healing period and then have high rates of infections and relapse.16

Fresh-frozen homologous bone, because of its osteoinductivity and osteoconductivity, has been widely used in different operative theaters, such as orthopedic surgery and spine surgery.17,18 Recently, several authors described the use...
of fresh-frozen bone (FFB) allografts as a reliable surgical alternative in maxillofacial and oral surgery.\textsuperscript{19-21}

Although many different grafting materials have been described, there is still no consensus in the literature. We present herein our clinical experience with 10 cases of sliding genioplasty using FFB allografts as a new grafting material.

### METHODS

The present study includes 10 patients who underwent vertical height augmentation genioplasty by means of a horizontal sliding osteotomy of the symphysis with interpositional homologous FFB allografts at the Department of Oral and Maxillofacial Surgery, Policlinico G. B. Rossi, University of Verona, Verona, Italy, from 2008 to 2009. All cases were performed by 1 surgeon (D.B.). Informed consent about the surgical procedure, the grafting material, and the use of personal data for research purposes, approved by the local research ethics committee and written by the local tissue bank, was obtained from patients. All of these patients, 3 men and 7 women, were white. Genioplasty was associated with bimaxillary surgery in 4 cases and with rhinoplasty in 6 cases.

Initial consultation included a complete medical history and physical examination. Dental history was investigated by means of an occlusal evaluation, standard facial photographs, lateral cephalogram, anterior-posterior skull radiography, and panoramic. In addition, in cases of dentoskeletal deformities, dental models were developed. Functional and cosmetic goals were determined according to the patients’ expectations and to the facial analysis.

All surgical procedures were performed with the patient under general anesthesia. After local infiltration with anesthetic and vasoconstrictor, a vestibular incision of the mucosa was made only superficially, 6- to 8-mm labial to the depth of the oral vestibulum, and then directed horizontally to the alveolar process from one cuspid to the other. After an accurate dissection of the branches of the mental nerves, the chin prominence was gently degloved, providing a direct access to the anterior surface of the symphysis. The osteotomy line was marked. Osteotomy of the chin was then performed by means of a piezoelectric scalpel (Piezosurgery Medical II; Mectron) using the Piezosurgery MT1-10 insert (Mectron), and when the osteotomy was completed, the sliding segment was sectioned.

After fixation with 3 titanium bone plates (2.0 Orthognathic system; Osteomed), fresh-frozen corticospinous bone blocks were shaped and positioned through the bone gap. Fresh-frozen morcellized bone chips were then used to fill in continuity solutions between the bone grafts and the native bone to make the bone surface regular. Bioengineered membranes (Geistlich Biogide; Geistlich Pharma AG) were positioned as a barrier on the anterior surface to prevent migration of FFB chips and to reduce the ingress of saliva and oral bacterial flora. Closure was then obtained with resorbable sutures (Polysorb 4.0; Covidien). Lengthening of the chin was obtained in each case, with a mean value of 3.5 mm, while the mean value of chin advancement was 3.7 mm (Table).

Fresh-frozen bone was prepared in chips or blocks in a sterile environment by the Regional Tissue Bank of Treviso. The iliac crests were removed in a sterile setting. A sample was taken from the surface of the bone for bacterial studies, together with a bone biopsy specimen, and stored in 4 vials. The epiphysis or the iliac crest were then maintained in a refrigerator at −80°C. The FFB was a mineralized, nonirradiated, and only disinfected frozen homologous bone.

Lateral cephalograms of hard and soft tissues were taken preoperatively, immediately, and 1 month, 6 months, and/or a minimum of 1 year postoperatively. An orthognathic patient underwent a computed tomographic (CT) cone-beam examination preoperatively and 6 and 12 months after surgery. A comparison study of hard- and soft-tissue changes after genioplasty in all 10 patients was performed with immediately postoperative and 1-year postoperative CT scans. The stability of the grafted FFB was assessed by measuring vertical resorption through the comparison of hard- and soft-tissue changes. The superimposition of preoperative and postoperative lateral cephalogram allowed for checking any eventual height resorption of the skeletal chin.

One patient underwent the removal of osteosynthetic plates, and a bone biopsy was taken from the anterior surface of the interpositional graft by means of a trephine burr (diameter, 3 mm). Bone cores were immediately fixed in 10% neutral buffered formalin for 24 to 36 hours, decalcified in EDTA disodium salt acid buffer (Osteoal; Bio-optica) for 3 hours, and conventionally embedded in paraffin. Sections were immunostained with the following antibodies: CD56/NCAM (Clone 123C3.D5; NeoMarkers), cathespin K (Clone CK4; Novocastra), tenasin (Clone 49; Novocastra), and CD34 (Clone QBEND/10; Novocastra). Heat-induced antigen retrieval was used when requested by the standardized protocol. All samples were processed using a sensitive “Bond Polymer Refine” detection system in an automated Bond immunostainer (Vision-Biosystem; Menarini). Sections incubated without the primary antibody served as a negative control. The bone cores were histologically analyzed to investigate the nature of the bone.

### Table. Surgical Treatment and Related Amount of Bone Shift

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Type of Surgery</th>
<th>Advancement, mm</th>
<th>Vertical Height Augmentation, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/22</td>
<td>Genioplasty, rhinoplasty, and mandibular angles remodeling</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2/F/24</td>
<td>Genioplasty and rhinoplasty</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>3/F/20</td>
<td>Bimaxillary orthognathic surgery and genioplasty</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4/F/26</td>
<td>Genioplasty and rhinoplasty</td>
<td>4</td>
<td>3</td>
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<tr>
<td>5/F/21</td>
<td>Bimaxillary orthognathic surgery and genioplasty</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>6/M/29</td>
<td>Genioplasty and rhinoplasty</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>7/R/22</td>
<td>Genioplasty and rhinoplasty</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8/F/23</td>
<td>Bimaxillary orthognathic surgery and genioplasty</td>
<td>4</td>
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<tr>
<td>9/F/26</td>
<td>Genioplasty and rhinoplasty</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>10/M/19</td>
<td>Bimaxillary orthognathic surgery and genioplasty</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mean value</td>
<td></td>
<td>3.7</td>
<td>3.5</td>
</tr>
</tbody>
</table>

\[\text{Mean value} = 3.7\text{ mm (Table)}.\]
the presence of inflammatory cells throughout the grafting material, and the entity of osseointegration and healing.

RESULTS

REPORT OF A CASE

A 22-year-old woman was referred to the Department of Oral and Maxillofacial Surgery, Polyclinico G. B. Rossi, University of Verona, because of a severe hypoplasia of the chin and latero-deviation of the nose (Figure 1). The patient did not allow any orthodontic and orthognathic treatment and just asked for an aesthetic correction of the facial balance with minimally invasive surgery. According to the patient’s expectations, a sliding genioplasty and a simultaneous lipofilling of the upper lip associated with a rhinoplasty were planned. Fresh-frozen corticocancellous and morcellized bone was used to fill the vertical gap between the sliding bone segment and the mandible (Figure 2). Open rhinoplasty was then performed.

After a follow-up of 12 months, no adverse reaction occurred (Figure 3). Lateral cephalogram and frontal cranial radiography at 12 months after surgery showed a complete healing of the bone gap of the chin (Figure 4). Nevertheless, the patient needed to extract all third molars, and she asked to undergo plate removal at the same time. Twelve months after surgery, extraction of third molars and plate removal were performed and, with the patient consent, a bone biopsy specimen was harvested (Figure 5).

CLINICAL OUTCOMES AND HISTOLOGICAL RESULTS

The median follow-up time was 14 months. Immediate healing was achieved without any complications or adverse reactions. All patients healed without any major postoperative problems. No paresthesia of the mental nerves occurred.

The clinical outcome was stable in every case, without any aesthetic adverse effects or vertical height modification. In lateral cephalograms and panorex, bone healing and integration to upper and lower chin bone was completed within 8 months after surgery in all cases. No changes of hard tissue were observed within 14 months after surgery.

The histological analysis at the time of implant fixture placement revealed new bone formation and simultaneous grafted bone chip resorption (Figure 6A). Homologous bone chips were embedded in newly formed bone. Direct connection between homologous bone chips and newly formed bone trabeculae was also clearly displayed in the sections. Newly formed bone was characterized by lacunae containing osteocytes (Figure 6B). Bone-lining cells and osteoblasts expressing CD56/NCAM were observed on the boundary with the newly formed bone (Figure 6C). The newly formed bone had an inner space filled with a well-vascularized connective tissue with evidence of ongoing fibrogenesis (as shown by the expression of the extracellular matrix protein tenascin) (Figure 6D), effective angiogenesis, and no sign of inflammation or foreign body reaction (as demon-
strated by CD34 immunostaining) (Figure 6E). Osteoclast activity was also revealed in sections immunostained for cathepsin-K. The osteoclast activity seemed to be effective in both homologous bone trabeculae and newly formed bone trabeculae. Remains of homologous bone chips, characterized by empty lacunae, seemed to be well integrated within the bone tissue and showed an intense osteoclastic resorption.

Each patient underwent a radiological follow-up that provided a lateral cephalogram 7 days after surgery and 1 year after surgery. The cephalometric data confirmed that no alterations of bone height or bone width of the chin occurred.

**COMMENT**

The vertically shortened chin represents an anatomical facial deficiency commonly managed by maxillofacial and plastic surgeons because of its fundamental importance for global harmony of the face. Although vertical deficiency of the facial lower third is a proper character of class II dento-facial deformity and, for this reason, the orthodontic and orthognathic surgical treatment is commonly associated with sliding genioplasty for chin correction, several patients are not interested in such treatment option. Moreover, patients affected by facial lower-third hypoplasia and associated nasal deformities often complain only about the aesthetic appearance of their nose. The importance of the chin projection on the global aesthetic facial impression is often unknown. Regardless, the vertically shortened chin represents an anatomical defect of the mandibular bone profile with a direct influence in the aesthetic appearance. A complete knowledge of facial analysis is then required to obtain a precise evaluation of each pathological scenario. A maxillofacial surgeon should be able to propose the best sur-
gical option to correct all the possible deformities of the facial lower third, such as class II dentofacial deformities and isolated chin retrusion.10

The use of interpositional grafts in mandibular osteotomies for sliding genioplasty is not widely reported in the literature. There are limited studies that describe the use of various material in chin osteotomies. The use of interpositional grafts facilitates bone healing because it provides a matrix and a layer for secondary ossification and, furthermore, represents a static stop to relapse and to an eventual soft-tissue herniation. Actually, interpositional grafts provide an acceleration of bony union and reduce relapse.

It has been reported that interpositional grafts for sliding chin osteotomies could be performed with alloplastic material or autogenous bone. The advantages of the use of alloplastic material are simplicity, easy shaping, absence of a donor site morbidity, and absence of grafts reabsorption. The disadvantages are a higher rate of infections, graft failure, and reabsorption of the bone recipient site. The autogenous bone graft is currently more common than the alloplastic one and, moreover, represents the "gold standard" in oral and maxillofacial surgery. Autogenous corticocancellous bone graft harvested from the iliac crest is characterized by a lower rate of infection and no failure. The autogenous bone graft provides a predictable result because of its osteogenesis, osteoinductivity, and osteoconductivity. Nevertheless, it has been reported that corticocancellous bone from the iliac crest may have a high reabsorption rate and may result in higher morbidity because of donor site harvesting, as well as a higher cost due to a longer operative time.

Fresh-frozen corticocancellous and morcellized bone grafts can represent an attractive alternative because of their own biological and mechanical behavior. Primarily, allografts are osteoconductive and osteoinductive. Fresh-frozen allografts are not subjected to any chemical or mechanical treatment that may damage their own natural mechanical and protein structure. Therefore, FFB allografts provide a physical structure and a matrix for secondary ossification without the need for any cell transplant.

The advantages of using FFB include decreased operative trauma and time for the patient, decreased bleeding, no donor site morbidity, and a virtually unlimited amount of grafting material.22 Furthermore, the use of FFB reduces surgical costs because FFB represents a less expensive grafting material compared with the costs of autologous bone grafts harvesting and with the costs of all the other bone substitutes.

One of the main concerns about using FFB is the transmission of infectious diseases such as AIDS or hepatitis. In a recent article by Costain and Crawford,23 a careful review of the literature on allograft bone processing reported no new cases of human immunodeficiency virus (HIV) transmission since 1985. The estimated risk of HIV transmission is 1 of 1.6 million procedures. Strict allegiance to tissue bank guidelines on donor recruitment, bone harvesting and storage, and adequate record-keeping procedures make the use of safe allogeneic bone trustworthy. Actually, the risk of viral diseases transmission is less than that calculated after a blood transfusion. Although irradiation is widely used to sterilize allogeneic bone, the usual upper limit of gamma irradiation exposure to bone allograft in the United States is 25 kGy, and it has been reported that up to 50 kGy may be necessary to inactivate HIV. However, there is no evidence supporting the need to irradiate to improve immunotolerance and incorporation. Moreover, various studies have found that irradiation causes a clear weakening of the biomechanical and biological properties of the graft.24

The major objection to allografting is the potential risk of host immune response. Unlike other tissues used in transplantation surgery, there is no evidence to introduce the use of haplotype matching with allogeneic bone. No increase of anti-HLA antibodies has been detected after the use of frozen allogeneic bone. Although the in-

Figure 5. Front views 12 months after surgery and bone biopsy site.
A, Postoperative front view of the vestibular aspect of the chin 12 months after surgery. Complete osteointegration of the interpositional allograft is evident. B, After plates removal, the allograft was undetectable, as shown in this postoperative front view. C, Bone biopsy was performed to examine the quality of bone through the entire width of the allograft.

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fluence of freezing on the prevention of immune-based response has not been completely clarified, it has been demonstrated that FFB allografts present better results in terms of osteointegration and biomechanical properties, compared with fresh or freeze-dried bone allografts.23

Interpositional bone allografts have been covered in all cases by resorbable barrier membranes, according to the guided bone regeneration technique. Several studies demonstrated that the use of resorbable membranes, which disappear 1 month after surgery, favors bone allografts healing during the first phase of the osseointegration process. Indeed, the use of resorbable membranes makes it possible to maintain a free space and prevents the ingrowth of surrounding soft tissue. Many studies have demonstrated the predictability of guided bone regeneration in improving bone augmentation and reducing bone resorp-

Figure 6. Histological analysis. A, Histological section of entire bone biopsy specimen with evidence of homogeneous bone regeneration, graft reabsorption, and normal vascularization (hematoxylin-eosin, original magnification ×5). B, Magnified view of a grafted bone chip invaginated by a continued layer of newly formed bone. Osteocytes are observed inside the vital bone, while grafted bone is characterized by empty lacunae (hematoxylin-eosin, original magnification ×30). C, Histological findings 7 months after surgery. A continued front of bone apposition is evident all around the newly formed bone boundaries (CD 56/NCAM–clone 123c.D5 [NeoMarkers, immunostaining], original magnification ×10). D, Histological section showing the mature aspect of the bone architecture and a normal well-vascularized inner space (Clone 49 [Novocastra], original magnification ×50). E, CD34 immunostaining demonstrated effective angiogenesis and no sign of inflammation or foreign body reaction (Clone QBEND/10 [Novocastra], original magnification ×50).
tion after autologous or heterologous bone grafts, which could disturb bone healing, in order to regenerate new bone tissue in the previously free space.25

The use of bone allografts decreases costs by reducing operative time, morbidity, and hospitalization compared with autogenous bone and alloplastic materials. Sizing genioplasty using FFB allografts showed satisfactory and stable results in all patients, as demonstrated by the cephalometric analysis in all the study patients.

In conclusion, there are currently no studies in the literature, to our knowledge, that examine the use of FFB allograft in chin osteotomies. Our clinical experience indicates that the use of this material, already applied in many fields of medicine and in oral and maxillofacial surgery, has proved itself to be a reliable alternative for interpositional bone grafting in sliding osteotomies. Therefore, assuming that further extensive follow-up studies will be necessary, FFB allograft can be considered an encouraging material in the treatment of chin deformities.

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Author Contributions: Dr Bertossi had full access to all of the data in the study and takes full responsibility for the integrity of the data and accuracy of the data analysis. Study concept and design: Bertossi, Albanese, Nocini, Trevisiol, and Procacci. Acquisition of data: Bertossi, Nocini, Trevisiol, and Procacci. Analysis and interpretation of data: Albanese and D’Agostino. Drafting of the manuscript: Bertossi, Albanese, Nocini, D’Agostino, Trevisiol, and Procacci. Statistical analysis: D’Agostino. Study supervision: Bertossi, Albanese, Nocini, and Procacci.

Conflict of Interest Disclosures: None reported.

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