Mandibular coronoid process grafting for alveolar ridge defects

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Objective. We describe the clinical results of mandibular augmentation with coronoid process bone grafts for dental implant insertion.

Study Design. Fifteen patients with vertical and transverse defects of the posterior alveolar process of the mandible were treated. All patients underwent mandibular rehabilitation with autogenous coronoid process bone grafts via minimal-access surgery. After 6 months, 40 dental implants were inserted.

Results. At the time of implant insertion, the grafted alveolar ridges showed mean transverse and vertical augmentations of 3.07 and 2.80 mm, respectively. At 24 months after implant surgery, the cumulative implant survival rate was 95% and mean marginal bone loss was 1.6 ± 0.18 mm. No complete bone graft loss or infection occurred.

Conclusions. Coronoid process bone grafts can be used to reconstruct moderate defects in edentulous alveolar processes. The insertion of the graft with minimal access in a tunneled fashion minimizes the risk of infection. (Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114:430-436)

Bone defects are common in the human mandible and are caused primarily by the premature loss of teeth due to periodontal disease or trauma. These defects usually cause a reduction in alveolar bone volume, rendering it inadequate for standard treatments with osseointegrated implants.[1]

The extensive resorption of alveolar bone is often the main cause of patient dissatisfaction with the functional and esthetic outcomes of dental prosthetic rehabilitation. Moreover, the insufficient height and width of the alveolar ridge make the mandibular anatomy particularly unfavorable for the successful placement of dental implants. To create favorable conditions for implant rehabilitation, different grafting materials and techniques are currently used to predictably augment the mandibular bone.[2]

In atrophic mandibles, autologous bone is widely accepted as the most appropriate grafting material.[3] Bone can be harvested intraorally from the retromolar areas, ramus, or symphysis, or extraorally from the ilium, tibia, or calvarium. These grafts differ regarding embryologic characteristics (endochondral vs. intramembranous ossification), type of bone (cancellous vs. cortical), morphologic and physical characteristics, volume of bone that can be obtained, rate of bone resorption, and donor site morbidity. The ideal bone graft is intramembranous in origin, is readily harvested, and has a high cortical component, minimal resorption rate, and adequate volume for facial-reconstructive purposes. The ideal donor site is close to the recipient site and should have minimal morbidity.

Although the perfect bone graft does not exist, the mandibular ramus and coronoid process exhibit many positive characteristics. These areas are reliable donor sites for mandibular-crest rehabilitation because they provide an adequate amount of dense bone, are valid for implant placement, and have short healing times.[4] The advantages of harvesting bone grafts from the ascending ramus instead of from the chin include the minimization of patient concern about altered facial contour and low levels of postoperative sensory disturbances and discomfort. However, the quantity of bone harvested from the ramus alone is often insufficient for mandibular crest reconstruction. Intraoral coronoidectomy is a commonly used maxillofacial procedure to obtain surgical access and to treat fibrosis, coronoid hyperplasia, temporomandibular joint ankylosis, trauma, and temporalis muscle fibrosis. Its use in maxillomandibular and orbital floor reconstruction has also been described.[5]

In 1999, Misch[6] described an alveolar augmentation procedure in which an external oblique ridge graft is harvested in conjunction with third molar extraction

Statement of Clinical Relevance

The coronoid process graft has its application in reconstructing moderate edentulous alveolar defects. Inserting the graft with minimal access, in a tunneled fashion, minimizes the risk of infection.

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before the placement of dental implants, thereby limiting the patient to a single surgical exposure. However, because that procedure did not include the harvesting of the coronoid process, the volume of bone available for grafting was limited. Moreover, the wide exposure of the mandibular body increased the risk of infection and resorption at the recipient site. Coronoid process grafts have been used successfully for the reconstruction of different facial bone defects.[7-9]

We think that a mono- or bilateral coronoid process bone graft, with or without the ascending ramus of the mandible, may be a reliable source of bone for the reconstruction of mandibular crest defects with minimal morbidity and little risk of infection or resorption if the graft is inserted in a tunneled manner through a small anterior incision. In the present study, we evaluated the clinical and radiologic outcomes of oral implants inserted in mandibular alveolar processes that had been reconstructed with coronoid bone grafts using a minimal tunneled surgical approach.

MATERIALS AND METHODS

The study sample included 15 consecutive patients (9 men, 6 women) with a mean age of 54.6 (range 40-70) years who underwent implant rehabilitation to treat posterior alveolar mandibular defects. Ten patients were nonsmokers, and 5 smoked ≤10 cigarettes per day. Inclusion criteria for this study were the presence of a transverse or vertical defect in the posterior alveolar crest of the mandible, contraindication for primary oral implants, clinical and computerized tomography (CT) evaluation, good oral hygiene, and patient motivation. Exclusion criteria were uncontrolled diabetes, pregnancy or lactation, substance abuse, psychiatric problems, severe bruxism or clenching habit, history of irradiation in the head and neck area, and severe mouth opening limitation.

All potentially eligible patients passed through the following clinical phases. First, the patients provided preliminary written informed consents and underwent anamnestic and clinical evaluations. Preliminary screening, including intraoral and panoramic radiographs and cone-beam CT, was performed to evaluate each patient's eligibility. In the second phase, eligible patients received oral hygiene maintenance training, and impressions and baseline photographs were taken. Study casts were mounted in a mean-value articulator, and a diagnostic wax set-up was created.

Each patient was then scheduled for a 2-stage surgery consisting of initial bone grafting of the atrophic sites and dental implant placement 6 months later. All surgical procedures were performed on an outpatient basis under local anesthesia. Diazepam (10 mg Valium; Roche-Hoffman la Roche) was administered preoperatively as a sedative agent. Antibiotics (875 mg amoxicillin and 125 mg clavulanate) were given 2 hours before surgery and twice daily for 6 days thereafter. Gastric protection was also provided (20 mg omeprazole on the day of surgery and once daily for 6 days thereafter). A nonsteroidal antiinflammatory drug (NSAID; 100 mg ketoprofen) was administered twice daily for 4 days after surgery. Each patient rinsed with chlorhexidine gluconate (0.2%) for 1 minute before the intervention and twice daily for 2 weeks after surgery.

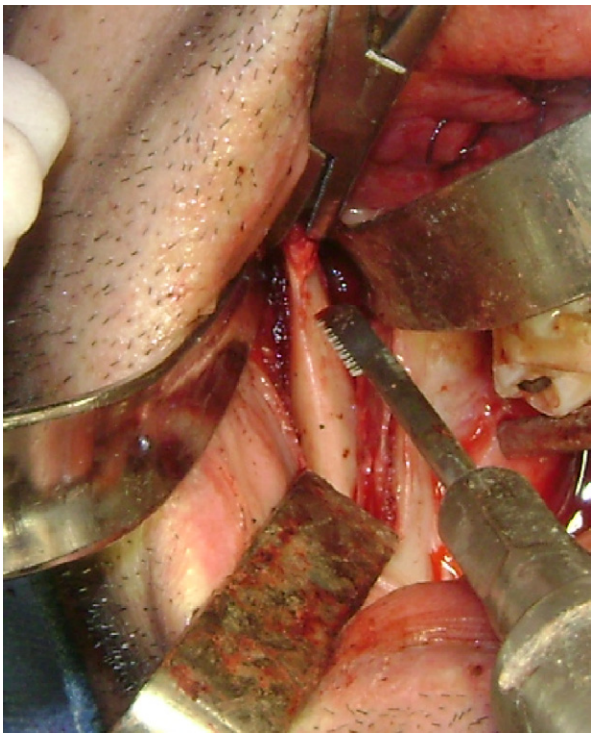

Fig. 1. Coronoid bone graft harvesting.

All surgeries were performed by the same operator, who was well trained in orthognathic and preprosthetic surgery. In the first surgical step, bone grafts were harvested through a 3-cm-long intraoral incision in the inferior lateral vestibule, similar to that used in a sagittal split-ramus osteotomy. The soft tissues and periosteum were elevated from the ramus and coronoid process, and the lingual and vestibular tissues were reflected in the subperiosteal plane to allow the superior insertion of a notched ramus retractor and Obwegeser retractors into the medial and lateral aspects of the sigmoid notch. The tendinous attachments of the temporalis muscle to the coronoid process were then detached, and the notched ramus retractor was replaced with a curved Crile clamp. A vertical/oblique osteotomy was made on the medial surface of the ascending ramus with a small reciprocating saw from the sigmoid notch toward the outer mandibular cortex in a high/medial–low/lateral direction (Figures 1

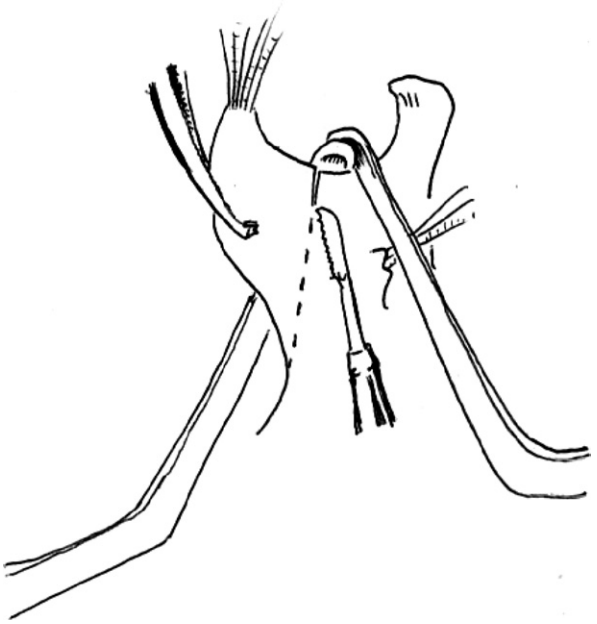

Fig. 2. Drawing illustrating the procedure.

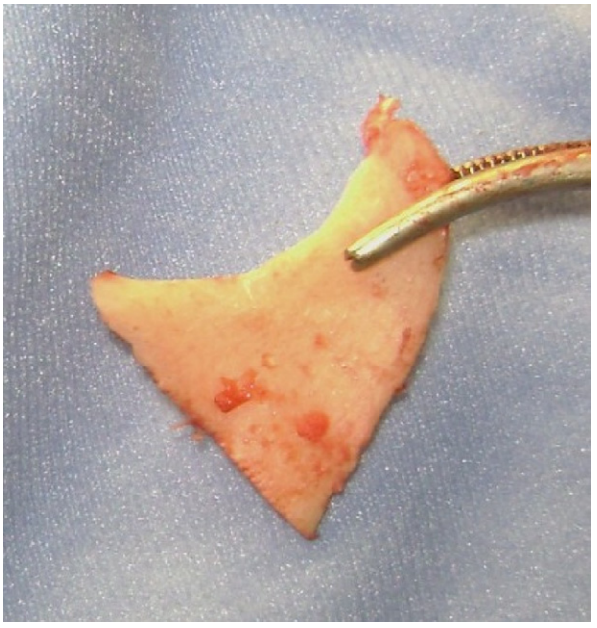

Fig. 3. Amount of bone available for grafting.

and 2). This osteotomy was performed anterior to the antilingula to avoid the inferior alveolar neurovascular bundle through the full thickness of the ascending ramus/coronoid. After the osteotomies were completed, straight chisels were pivoted to deliver the graft in toto (Figure 3). Great care was taken to avoid damage to the inferior alveolar neurovascular bundle while delivering the graft.

After harvesting, the bone grafts were reshaped appropriately using a round bur; minimal recontouring was performed to smooth the surface and fit the recipient site.

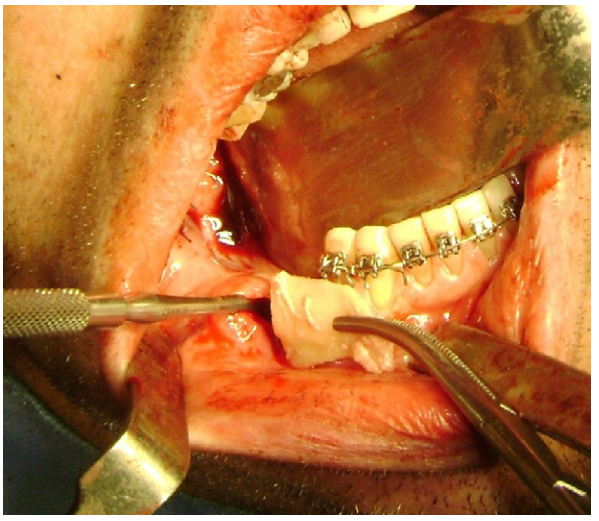

Fig. 4. Subperiosteal tunnel to expose the alveolar ridge.

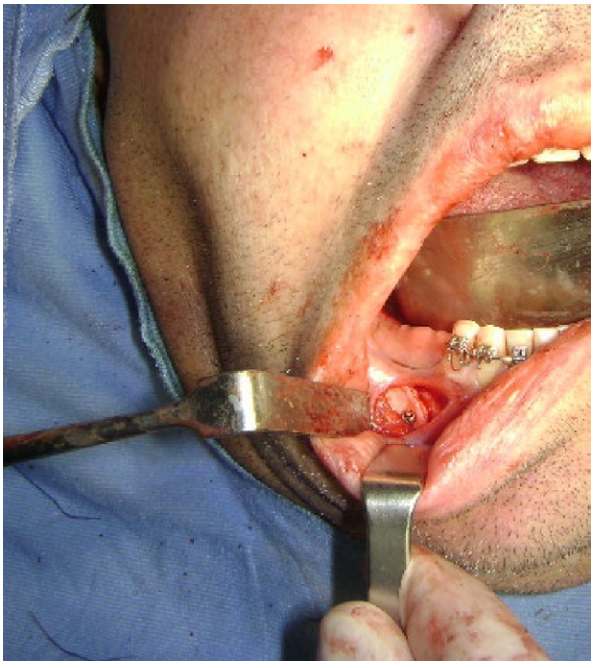

Fig. 5. Stabilization of the graft with a single screw.

The donor site was closed with 3/0 vicryl sutures. A novel minimal approach to the atrophic crest was then used to reduce graft exposition in the oral cavity. Surgical access to the native bone differed from that obtained using the classic direct approach. To avoid suturing over the bone graft and the permanent presence of saliva on the surgical wounds, we did not use crestal incisions; instead, we made a small (~1 cm) angulated incision in the inferior vestibule, just anterior and superior to the mental foramen. The mental nerve was isolated and reflected inferiorly. The ridge of the lateral crest was then exposed via a subperiosteal tunnel. With a gentle blind periosteal elevation and

Table I. Analytic description of the horizontal amount of bone augmentation obtained and grafts resorption

Case	Residual ridge width	Lateral augmentation at bone grafting	Postaugmentation width	Reentry width	Reentry lateral augmentation	Resorption
1	3.5 mm	3.5 mm	7.0 mm	6.0 mm	2.5 mm	1.0 mm, 28.5%
2	2.5 mm	4.0 mm	6.5 mm	6.0 mm	3.5 mm	0.5 mm, 12.5%
3	3.0 mm	5.0 mm	8.0 mm	7.0 mm	4.0 mm	1.0 mm, 20.0%
4	2.0 mm	4.0 mm	6.0 mm	5.5 mm	3.5 mm	0.5 mm, 12.5%
5R	3.5 mm	4.0 mm	7.5 mm	7.5 mm	4.0 mm	0
5L	3.0 mm	2.5 mm	5.5 mm	5.0 mm	2.0 mm	0.5 mm, 20.0%
6	2.0 mm	5.0 mm	7.0 mm	60.0 mm	4.0 mm	1.0 mm, 20.0%
7R	3.0 mm	2.0 mm	5.0 mm	4.5 mm	4.5 mm	0.5 mm, 25.0%
7L	2.5 mm	5.0 mm	7.5 mm	7 mm	4.5 mm	0.5 mm, 10.0%
8	3.0 mm	4.0 mm	7.0 mm	6.0 mm	3.0 mm	1.0 mm, 25.0%
9R	3.0 mm	2.0 mm	5.0 mm	4.5 mm	1.5 mm	0.5 mm, 25.0%
9L	2.0 mm	4.0 mm	6.0 mm	5.0 mm	3.0 mm	1.0 mm, 25.0%
10	2.5 mm	5.0 mm	7.5 mm	7 mm	4.5 mm	0.5 mm, 10.0%
11R	3.0 mm	2.0 mm	5.0 mm	5.0 mm	5.0 mm	0
11L	2.0 mm	4.0 mm	6.0 mm	5.5 mm	3.5 mm	0.5 mm, 12.5%
12	3.0 mm	4.0 mm	7.0 mm	6.0 mm	3.0 mm	1.0 mm, 25.0%
13	3.0 mm	2.0 mm	5.0 mm	4.5 mm	1.5 mm	0.5 mm, 25.0%
14	3.0 mm	3.0 mm	6.0 mm	5.5 mm	2.5 mm	0.5 mm, 16.6%
15R	3.5 mm	1.5 mm	5.0 mm	5.0 mm	1.5 mm	0
15L	2.0 mm	4.0 mm	6.0 mm	5.0 mm	3.0 mm	1.0 mm, 25.0%
Mean	2.75 mm	3.52 mm	6.27 mm	5.67 mm	3.07 mm	0.6 mm, 16.88%
SD	0.50 mm	1.17 mm	1.01 mm	0.91 mm	1.12 mm	0.34 mm, 9.39%

Table II. Analytic description of the amount of vertical bone augmentation obtained and grafts resorption

Case	Residual ridge height	Vertical augmentation at bone grafting	Postaugmentation height	Reentry height	Reentry vertical augmentation	Resorption mm
1	7.0 mm	5.0 mm	12.0 mm	11.0 mm	4.0 mm	1.0 mm, 20.0%
2	7.0 mm	4.5 mm	11.5 mm	11.0 mm	4.0 mm	0.5 mm, 11.1%
3	8.5 mm	3.5 mm	12.0 mm	11.0 mm	2.5 mm	1.0 mm, 28.5%
4	6.5 mm	5.0 mm	11.5 mm	9.0 mm	2.5 mm	2.5 mm, 50.0%
5R	9.0 mm	2.0 mm	11.0 mm	10.5 mm	1.5 mm	0.5 mm, 25.0%
5L	7.0 mm	3.5 mm	10.5 mm	10.0 mm	3.0 mm	0.5 mm, 14.2%
6	8.0 mm	4.5 mm	12.5 mm	11.0 mm	3.0 mm	1.5 mm, 33.3%
7R	8.5 mm	2.0 mm	10.5 mm	10.0 mm	1.5 mm	0.5 mm, 25.0%
7L	8.5 mm	3.0 mm	11.5 mm	10.5 mm	2.0 mm	1.0 mm, 33.3%
8	7.5 mm	4.5 mm	12.0 mm	10.5 mm	3.0 mm	1.5 mm, 33.3%
9R	8.5 mm	3.5 mm	12.0 mm	11.5 mm	3.0 mm	0.5 mm, 14.2%
9L	8.0 mm	4.0 mm	12.0 mm	11.0 mm	3.0 mm	1.0 mm, 25.0%
10	7.0 mm	4.0 mm	11.0 mm	9.5 mm	2.5 mm	1.5 mm, 37.5%
11R	9.0 mm	4.5 mm	13.5 mm	13.0 mm	4.0 mm	0.5 mm, 11.1%
11L	7.5 mm	3.5 mm	11.0 mm	10.5 mm	3.0 mm	0.5 mm, 14.2%
12	8.5 mm	2.5 mm	11.0 mm	10.5 mm	2.0 mm	0.5 mm, 20.0%
13	8.0 mm	4.0 mm	12.0 mm	11.0 mm	3.0 mm	1.0 mm, 25.0%
14	7.5 mm	4.0 mm	11.5 mm	10.5 mm	3.0 mm	1.0 mm, 25.0%
15R	9.0 mm	3.5 mm	12.5 mm	11.5 mm	2.5 mm	1.0 mm, 28.5%
15L	7.0 mm	4.5 mm	11.5 mm	10.0 mm	3.0 mm	1.5 mm, 33.3%
Mean	7.87 mm	3.77 mm	11.65 mm	10.67 mm	2.8 mm	0.97 mm, 25.37%
SD	0.78 mm	0.88 mm	0.74 mm	0.83 mm	0.73 mm	0.52 mm, 9.99%

palpation of the recipient site mucosa with the nondominant hand to drive the elevator, the dissection was carried out on the superior and medial aspects of the edentulous mandibular body (Figure 4). The molded bone graft was then inserted through the small incision until its thickest part was in direct contact with the atrophic area (veneer or onlay graft technique); the apex of the coronoid process was held to direct the bone fragment into the correct location.

Rigid fixation of the correctly placed grafts was mandatory. Stabilization was generally achieved by placing a single titanium screw (2 mm) in the most anterior (and thinnest) part of the graft (Figure 5). Antirotational stability was obtained by placing the

Table III. Pre- and postoperative information about the patients

Patient	Sex/age	Defect localization	Nature of defect*	No. of implants inserted
1	Male/40	Left	Combined	2
2	Female/50	Left	Combined	2
3	Male/56	Right	Combined	2
4	Male/64	Left	Combined	2
5	Female/45	Bilateral	Combined	4
6	Male/48	Right	Combined	2
7	Male/61	Bilateral	Combined	4
8	Female/57	Right	Combined	2
9	Female/63	Bilateral	Combined	4
10	Female/70	Right	Combined	2
11	Female/42	Bilateral	Combined	4
12	Male/53	Right	Combined	2
13	Male/67	Right	Combined	2
14	Male/55	Right	Combined	2
15	Male/49	Bilateral	Combined	4

*Transverse and vertical defects are described as "combined."

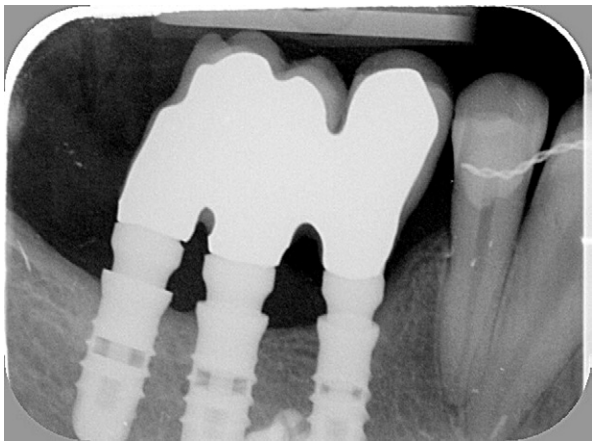

Fig. 6. Periapical radiographs of implants.

distal part of the graft in contact with the anterior aspect of the ramus. In this way, the bone grafts were completely covered by healthy uninterrupted mucosa and periosteum. When necessary, small bone chips from the ramus were used to fill gaps between the graft and native bone. A total of 20 grafts were inserted in 15 patients; lateral and vertical augmentations are listed in Tables I and II, respectively.

At 5-6 months after graft placement, the volume of the grafted ridges was assessed with the use of cone-beam CT, and oral implants were placed under local anesthesia. A total of 40 titanium, roughened-surface, tapered, submerged fixtures (Exacone implants; Leone, Firenze, Italy) were placed in 15 patients: 2 implants were placed in each grafted side, and 5 patients underwent bilateral treatment (Table III). Implant lengths ranged from 8 to 10 mm, and implant diameters were 4.0 or 4.65 mm. The implants were loaded with provisional acrylic crowns after 4 months, and definitive prosthetic restoration was initiated an average 3 months later.

Table IV. Life table analysis for implant success

Months	Patients	Implants	Failure	CSR
0-6	15	60	0	100%
6-12	15	58	2	96.7%
12-24	15	58	0	96.7%

CSR, Cumulative survival rate.

Table V. Perimplant marginal bone levels, mean values per patient, mm

	Implant insertion	6 mo	12 mo	24 mo
Mean	0.2	1.3	1.5	1.6
SD	0.18	0.17	0.17	0.18
Patients	15	15	15	15

Follow-up visits were scheduled for 7 days after bone grafting and then once monthly until implant surgery. Radiologic control was achieved with periapical radiographs taken just before implant surgery and at 6, 12, and 24 months after fixture placement with the use of a long-cone paralleling technique (Figure 6). The reference points for radiographic evaluation were the implant platform (horizontal implant-abutment interface) and the first bone-implant contact. Marginal bone remodeling was assessed by calculating the difference between the measurement obtained at each examination and the baseline value. Mesial and distal bone height measurements were averaged for each implant. Radiographs were retaken when the image quality was poor. An independent radiologist used a caliper to measure bone height. Descriptive statistics were used to analyze implant survival rate and bone levels at baseline and at 6, 12, and 24 months. Approval was obtained from the Ethical Committee of the University of Sassari for this study, and the clinical investigation followed the guidelines of the Helsinki Declaration.

RESULTS

No patient withdrew from the study. The follow-up period was 24 months after implant surgery. The postoperative period was uneventful for all but 1 patient, who underwent a second implant surgery to replace 2 failed implants. Two implants were lost after 6 months, at the time of provisional prosthesis removal. All remaining implants were loaded successfully, resulting in a cumulative 24-month survival rate of 95% (Table IV). Peri-implant marginal bone levels reported to the patients are presented in Tables V and VI: at 24 months, the mean marginal bone loss was 1.6 ± 0.18 mm. Some minor complications were noted after grafting surgery;

Table VI. Perimplant marginal bone levels, values per patient, mm

Patient	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Insert	0.3	0.0	0.2	0.1	0.3	0.5	0.0	0.0	0.3	0.4	0.3	0.6	0.3	0.2	0.1
6 mo	1.0	1.1	1.4	1.3	1.2	1.2	1.0	1.5	1.5	1.5	1.3	1.0	0.7	0.9	0.9
12 mo	1.2	1.3	1.5	1.6	1.4	1.3	1.2	1.7	1.6	1.6	1.4	1.2	0.8	1.0	1.0
24 mo	1.3	1.4	1.6	1.7	1.6	1.5	1.1	1.9	1.7	1.6	1.4	1.3	1.1.	1.1	1.1

Table VII. Patients' masticatory satisfaction 24 months after implant surgery

	No	*Not sure*	*Yes*
Has the fixed mandibular prosthesis improved your masticatory function?	1	0	14
Was it worth the cost?	1	1	13
Would you undergo the same therapy again?	1	1	13

1 patient presented with prolonged (>30 days) facial swelling, 2 patients complained of moderate pain at the grafted site for ~1 month, and 1 patient showed minimal graft exposition in the oral cavity at 1 month after surgery because of a small tear in the covering soft tissues. This problem was resolved with bone remodeling and daily washing of the wound with saline solution for 15 days.

Patient satisfaction was very high. No patient experienced long-term postoperative sensorial nerve disturbance. All patients except 1 reported improved masticatory function with the implant-supported mandibular prostheses (Table VII).

DISCUSSION

Preprosthetic reconstructive surgery of the resorbed mandible must create sufficient high-quality bone for implant placement. Several procedures have been proposed to achieve alveolar ridge augmentation in partially edentulous patients.[2,10] An autogenous bone block graft is one of the preferred methods for many types of augmentation procedures because it secures both a source of osteogenic cells and a rigid structure for mechanical support. After grafting, the inflammatory process continues and organizes, the dense fibrous stroma becomes highly vascular, and the graft begins the revascularization process at approximately day 10. This vascular ingrowth is responsible for the osteogenic potential of the graft. Autogenous cortical grafts of intramembranous lineage offer faster revascularization and healing and undergo resorption at a slower rate than bone of endochondral origin. Another advantage of cortical block grafts is that they are more resistant to failure than are grafts of mostly cancellous origin (hip, rib, tibia), even if the graft is exposed to the oral environment. Moreover, in accordance with the literature, the reported resorption rates confirmed the excellent volumetric stability of the bone block grafts harvested from the ascending ramus.[11,12] Histologically, some studies have shown that the grafted bone contains extended parts of nonvascularized bone (NVB) with empty osteocyte lacunae at the time of implant placement. The survival of osteocytes depends on their close (<0.1 mm) proximity to nutrient vessels, and interruption of the blood supply results in avascular necrosis.[13] From a clinical point of view, the NVB must be replaced by vital bone before implant placement, because vital bone has better mechanical characteristics. Therefore, the rates of NVB resorption by osteoclast activity and the subsequent formation of new bone are important factors for the osseointegration of implants. Increasing evidence has indicated that osteocytes are mechanosensitive and thus play a crucial role in adaptive bone remodeling. The osteocytes of a graft may be involved in the recruitment of osteoclasts or in the modulation of their activity by secreting signaling factors that communicate with the bone surface and control the activity of bone surface cells, such as osteoblasts, osteoclasts, and bone-lining cells.[14,15] For these reasons, and because it provides a predictable outcome, autogenous bone remains the gold standard in alveolar-ridge reconstructive surgery.

Our clinical findings showed that 4-6 months was a sufficient period of time for the grafted bone to integrate successfully with the original mandibular bone and reach the proper stability for ideal implant placement. The ideal donor site for harvesting a sufficient volume of bone should therefore be readily accessible and allow shaping and contouring according to the recipient site requirements. Furthermore, the procedure should have minimal morbidity, be cost-effective for the patient, and have a proven success record. The advantages of using the mandibular ramus as a donor site include convenient surgical access and proximity to the recipient site. The obtainable grafts are of adequate sizes and contours for moderately sized maxillofacial defects. In particular, the use of the entire coronoid process has several advantages. First, the length and basal thickness of the graft are noticeably superior to those of bone grafts harvested from the outer cortex of the ramus in the retromolar area. Second, the risk of dysesthesia is lower in these grafts than in those taken from the chin area. The removal of the vestibular cortex of the mandibular angle often leaves the inferior bundle

in an "open roof" condition that can easily lead to alterations in sensitivity. Finally, the shape of the coronoid process facilitates its insertion under the mucosa when the edentulous posterior mandibular ridge is approached in a tunneled fashion; the tip of the graft can be held, and the thicker base can be pushed backward in a mesiodistal direction. When the thick base of the coronoid process reaches the correct location, a single bicortical screw can be placed to fix the small thin tip of the process to the vestibular cortex of the mandibular body.

The postoperative course is usually characterized by slight to moderate discomfort. The harvesting of bone from this location requires knowledge of the course of the inferior alveolar canal through the mandible to prevent neurovascular injury. We attribute the absence of inferior alveolar nerve injury in our patients to meticulous preoperative planning, precise execution of the osteotomies at the harvest sites, and gentle retraction of the small mucosal flaps at the recipient sites. Patient acceptance of this procedure is high because of the lack of cutaneous scarring and minimal discomfort, mostly reported as unusual traction feelings on the temporalis muscle; however, no patient in our sample reported pain. Other autogenous harvest sites, such as the iliac crest, tibial plateau, ribs, and calvarium, are distant, require sterile preparation, and can be associated with severe morbidity and complications.[16]

In conclusion, we think that the use of coronoid process grafts can be widely applied in reconstructive surgery to treat mandibular alveolar ridge defects. The amount and quality of bone that can be harvested provide the surgeon with adequate bone stock for alveolar reconstruction in moderately edentulous mandibles. The potential for dental implant placement simultaneously with ridge augmentation surgery remains controversial. Many authors have noted the improved esthetics and success of implant osseointegration when the implants are incorporated into a well vascularized recipient site. On the basis of our clinical experience, we agree with those authors; in recent years, we have preferred to use a 2-stage procedure in all of these cases to ensure the predictability of outcomes.

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