Intramembranous autogenous osseous transplants in aesthetic treatment of alveolar atrophy

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Intramembranous autogenous osseous transplants have been used in the restoration of osseous volume as the gold standard of alveolar ridge reconstruction (8–10, 25, 36, 44). Intramembranous ossification is characterized by the formation of osseous tissue without the intermediate stage of cartilage formation (5, 25, 36, 44). Intraoral donor sites include the maxillary tuberosity, mandibular symphysis, angle of the mandible, ramus and exostoses (8–10, 19, 23, 39, 42).

The mandibular symphysis provides primarily a cortical graft (10, 19, 23). Advantages of the mandibular symphysis transplant are short healing period, minimal resorption, maintenance of osseous density, intraoral access, proximity to the recipient site, low morbidity, minimal discomfort and no cutaneous scar (23). Convenient surgical access and proximity of donor and recipient sites reduce operative time and cost.

The objective of this chapter is to describe the mandibular symphysis transplant in the reconstruction of alveolar atrophy.

Presurgical considerations

Patient selection for osseous transplants includes a comprehensive medical history and dental evaluation. Medical history must be evaluated for systemic conditions to prevent surgical complications. Any disease or medication that alters the immune system or healing ability, such as non-controlled diabetes and smoking, may cause failure of surgical therapy.

Oral examination includes evaluation of teeth and anatomic changes of soft and hard tissues. Reduced vestibular depth, ridge morphology, location of the sinus and neurovascular bundle may limit surgical therapy. Radiographic examination is conducted to evaluate ridge defects and maxillary and mandibular anatomy. Diagnostic wax-up of the reconstructed defect determines graft requirements and allows fabrication of a surgical template. The surgical template ensures the precise placement of the transplant.

Anatomical considerations

Musculature

The chin musculature is composed of three mimetic muscle groups: mentalis, orbicularis oris and depressors (31, 35, 43).

Mentalis muscles are paired in the midline and control the posture of the chin. Opposing the roots of the incisors, superior fibers run horizontally and anterolaterally, inferior fibers run vertically downward and lateral fibers transverse laterally (31, 35). The mentalis muscle does not pass directly into the lower lip but provides indirectly the major vertical support for the lower lip (31, 43). After mentalis contraction, skin overlying the chin is compressed against the mandibular symphysis elevating the lower lip.

Orbicularis oris, a sphincteric expression muscle with no direct attach on the skeleton, covers the entire width of the lips. Superior and inferior fibers cross each other at the corner of the oral cavity. Muscle strength is minimally affected by the chin position (31).

Depressors are composed of two muscles: Depressor anguli oris and depressor labii inferiori. Depressor anguli oris arise from the canine-first molar region, enters at the corner of oral cavity and along with the platysma may form transverse fibers called the transversus menti (31, 35). Depressor labii inferioris is in a slightly anterior position and enters

Table 1. Cross-sectional area of fully edentulous mandible

Section	Total area ±SEM	Cortex ±SEM	Spongiosa ±SEM	Cortex:spongiosa ratio
12	96±5	57±3	42±3	1.35
13	96±3	58±3	38±2	1.53
14	95±3	59±2	37±2	1.59
15	100±2	57±3	44±3	1.30

Source: Schubert et al. (34).
Cross-sectional area values are expressed as the relative percentage of the total area at the symphysis±SEM, where the cross-sectional area at the symphysis equals 100%.
Cut 12: between the premolars.
Cut 13, 14: either side of the canine.
Cut 15: through the symphysis.

the orbicularis oris more medially. Depressors have little effect on the chin position and contribute to the oral continence (31, 43).

Extensive mentalis reflection may cause loss of facial contour by inversion of the lower lip and flattening of the labiomental fold (pseudoprognatism) (31, 32, 43). Adaway et al. (1) examined 47 patients and measured a 2.6-mm decrease in lower lip height, 2.5-mm increase in chin prominence and 1.3-mm anterior repositioning of both lips. To prevent reduction in lower lip height and inversion of the vermilion zone, Hillerup (18) suggested flaps no deeper than one third of the total distance from the vermilion border to mucogingival junction. When the entire symphyseal region is exposed, maintaining the integrity of the periosteum attached to the inferior segment may improve soft tissue readaptation (18, 23).

Mental nerve and the anterior plexus or incisor nerve

The inferior alveolar neurovascular bundle has two anterior terminal branches: the mental nerve and the anterior plexus or incisor nerve (7, 30, 35). The mental nerve can present a loop mesially to the mental foramen (30, 37). Radiographically, the length of the loop varies from 3 to 5 mm. However, dissection observations are not in accordance with radiographic estimations (7, 30). Bavitz et al. (7) dissected bilaterally 23 mental foramen regions and reported 0 to 7.5 mm radiographic length of the loop versus only 0 to 1.0 mm actual length.

After dissecting the anterior loop in 37 human mandibles, Solar et al. (37) reported that, in 22 cases, the mental nerve formed a siphon with the most anterior point of the canal at 5 mm (59%) and, in 15 cases, no loop was observed (41%). Rosenquist (30)

dissected the ramification of the inferior neurovascular bundle in 58 patients undergoing nerve transpositioning in the premolar region. In 43 patients no loop was observed (74%), in 13 cases the loop was 0.5 mm long (23%) and in 2 cases 1 mm long (3%).

There may be a tendency to radiographically overestimate the length of the anterior loop. However, the anterior plexus or incisor nerve can be of considerable thickness. Direct injury or traumatic edema of the epineurium may cause neurosensory dysfunction in the main branch of the nerve (7, 30).

Mandibular anterior teeth

Cuspids have the longest root in the mandibular anterior sextant (25 to 26 mm) followed by lateral incisors (23 to 24 mm) and central incisors (21 to 22 mm) (35). To preserve tooth vitality, a clearance of 5 mm from apices seems reasonable.

Osseous volume of mandibular symphysis

Canine-to-canine osseous volume was determined in 28 children by computed tomography. Maximum cancellous bone obtainable without injury to the adjacent teeth was 0.5 cm^3. Including the outer cortex, the value increased to 0.7 cm^3 (6).

More osseous volume would be obtainable in adults. However, no study in the literature describes the quantity and the quality of bone volume available in the interforamina region for intramembranous osseous transplant purposes. A few studies report the quantity and the quality of the bone of the symphysis area for other purposes such as oncology studies or maxillofacial studies to evaluate the areas more prone to fractures.

Schubert et al. (34) described the cross-sectional area of fully dentulous mandible in multiple regions. Ten adult hemimandibles with full dentitions were cut in 15 cross-sections. The cuts were made from the condyle anteriorly to the symphysis and numbered 1 to 15. Cuts from number 12 to 15 were referred as interforamina region. All cross-sectional areas were expressed as the relative percentage of the area found in symphysis cut number 15. Table 1 describes the data from that study.

Ulm et al. (41) evaluated the total area of jaw sections in 41 edentulous mandibles. The purpose of the study was to describe the pattern of resorption of the alveolar bone. The results showed that the mandible loses up to 60% of the bone substance during progressive atrophy. The greatest osseous reduc-
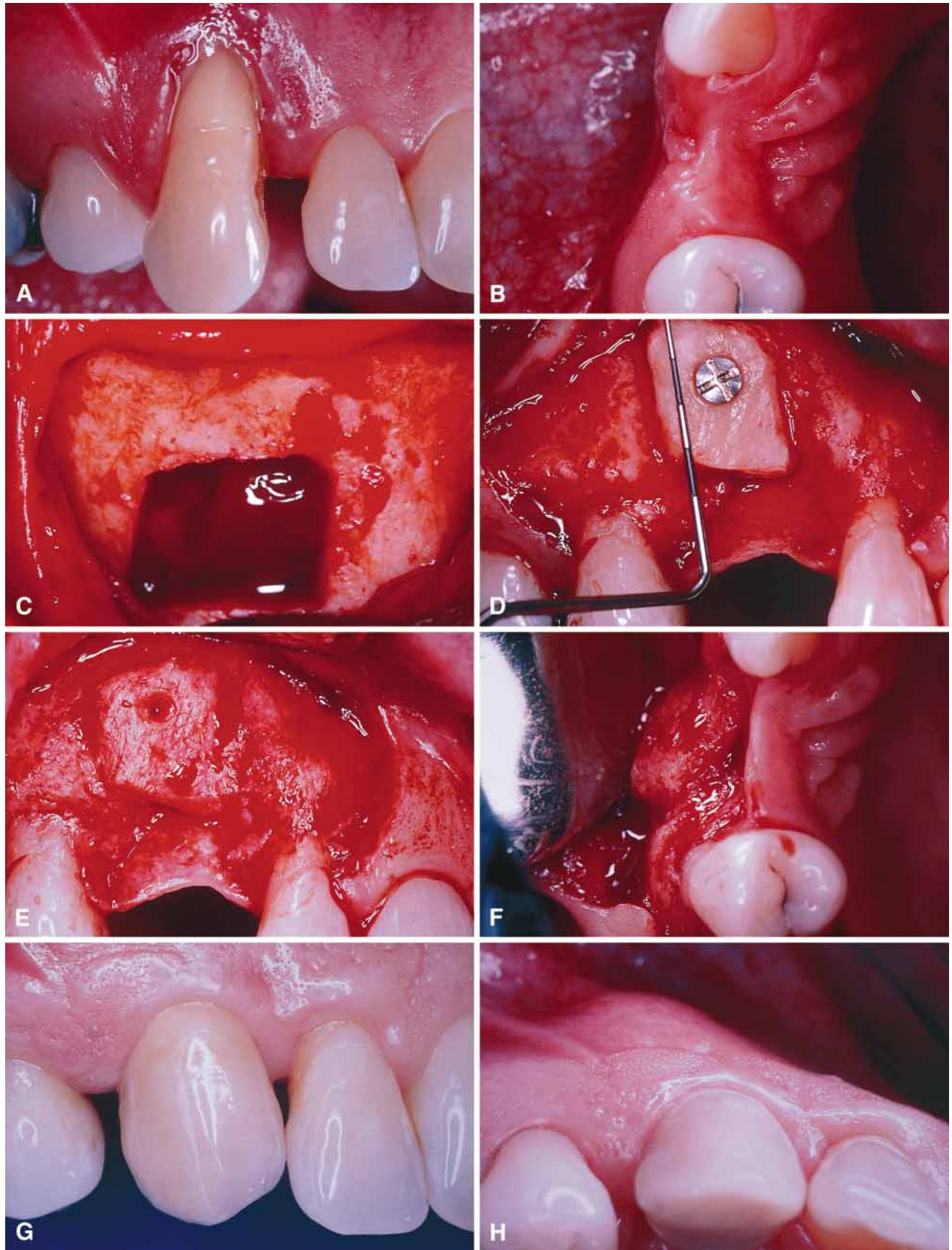
Fig. 1. **A.** Buccal view of the maxillary canine area prior to canine extraction due to severe periodontal attachment loss. **B.** Buccal view of the maxillary canine area after canine extraction. Note significant osseous deficiency. **C.** At the donor site, a full-thickness mucoperiosteal incision in the anterior buccal vestibule, well beyond and parallel to the mucogingival junction, extended posteriorly to the distal aspect of the mandibular canines. The mucoperiosteal flap is elevated inferiorly to expose the mandibular symphysis. The length and the morphology of the horizontal and vertical osteotomies depend on the size requirements of the transplant. **D.** Intramembranous transplant is sculpted to adapt over the osseous defect. Close adaptation of the transplant minimizes dead space formation. A 1.5-mm fixation screw stabilizes the transplant. **E.** Postoperative buccal view after a healing period of 4 months. **F.** Postoperative occlusal view after a healing period of 4 months. **G.** Buccal view of the canine area. An implant-supported crown restored the missing canine. **H.** Occlusal view of the canine area after soft and hard tissue restoration.

tion can be observed in the area of the second premolar and first molar. In the interforamina region, resorption was not as progressive as in the premolar and molar region (3, 4, 41).

Haribhakti (17) evaluated 36 adult dentate mandibles and reported that the cortical thickness of the symphysis area averaged 3.8 mm. In the para-symphysis area between the interforamina region, the cortical thickness averaged 4.1 mm.

Surgical technique

Flap reflection is performed at the recipient site prior to graft harvest. At 5 to 10 mm from the edges of the proposed transplant, two vertical incisions are placed at the line angles of the teeth and joined by an intrasulcular incision. Vertical incisions are composed of a horizontal component at the coronal part, an internally curved component at the mid-part and a cut back component at the apical part within the mucosa (Fig. 1d, e, 2b, 3a).
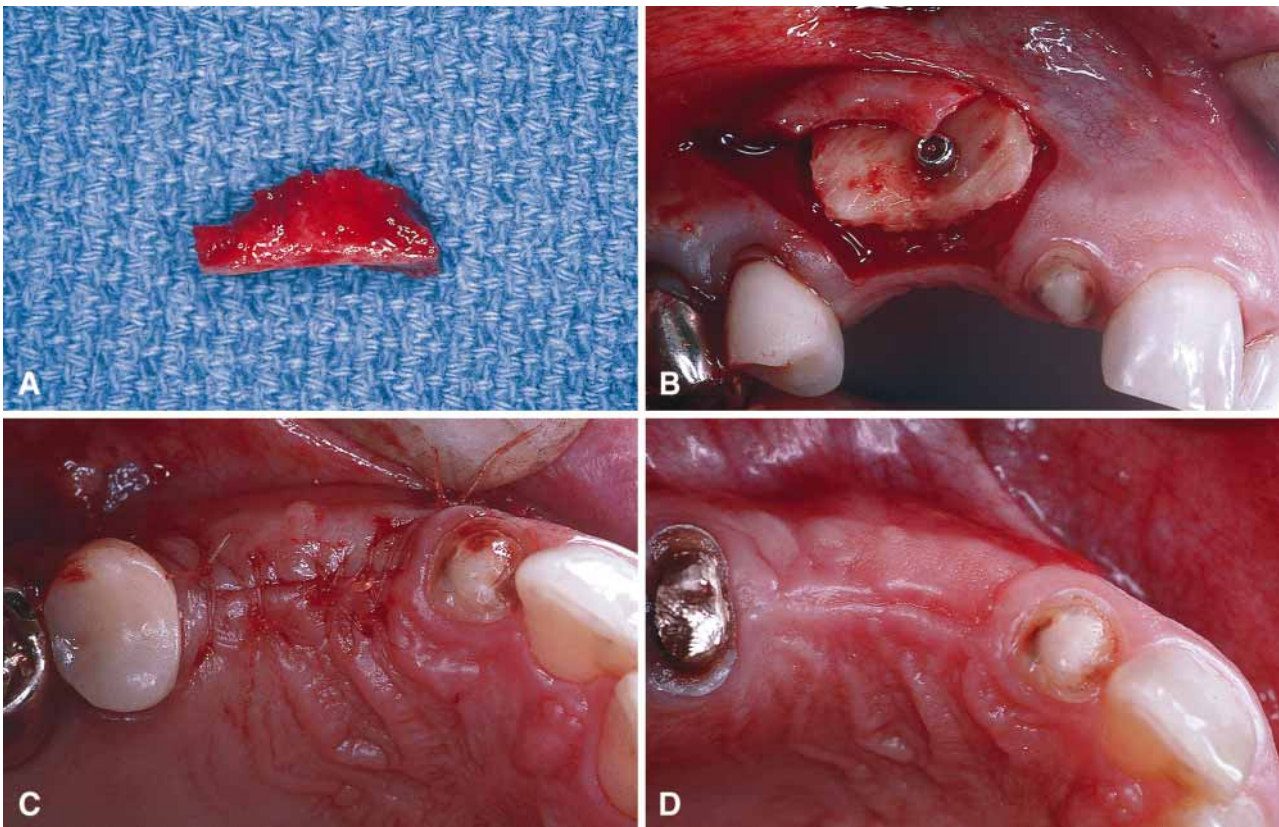

Fig. 2. **A.** Intramembranous transplant is sculpted to adapt over the osseous defect. Close adaptation of transplant minimizes dead space formation. **B.** Buccal surgical view of the maxillary canine-premolar area after the fixation of the osseous transplant. Careful soft tissue handling and minimal trauma to the recipient site are essential to successful incorporation of the transplant. **C.** Complete flap closure is a prerequisite for a successful treatment outcome. **D.** Postoperative occlusal view.
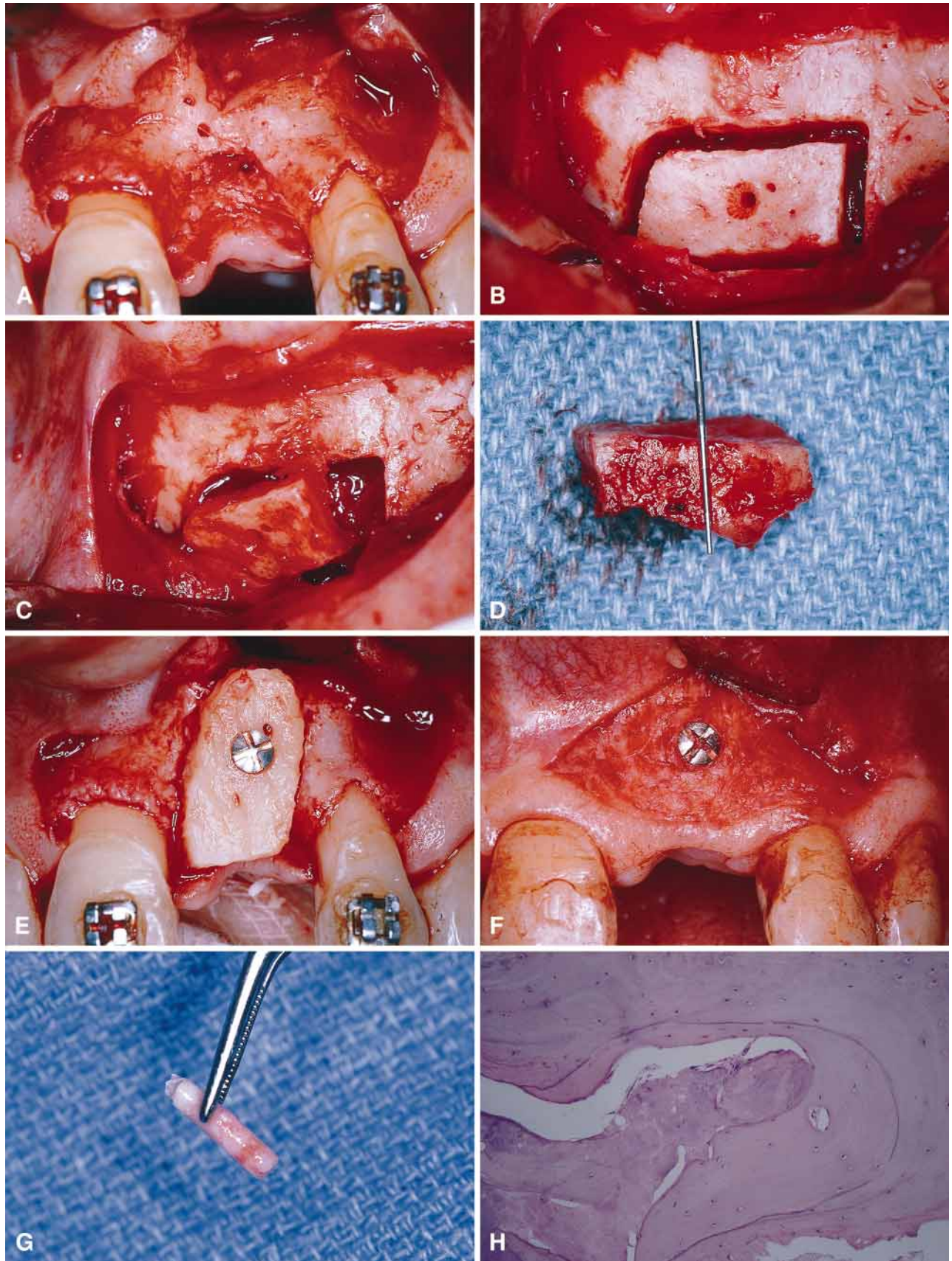
Fig. 3. **A.** Buccal surgical view of the maxillary central incisor area. Note extensive vertical and horizontal osseous deficiency. Vertical incisions are composed of a horizontal component at the coronal part, an internally curved component at the mid-part and a cut-back component at the apical part within the mucosa. **B.** At the donor site, prior to osteotomy, the locations of the apices of the mandibular anterior teeth are determined. Horizontal osteotomy is performed at least 5 mm inferior to the apices of the anterior teeth. The length and the morphology of the horizontal and vertical osteotomies depend on the size requirements of the transplant. **C.** Cortical osteotomies are progressively deepened until a desirable thickness has been achieved. A splitting osteotome is placed into the cuts and gently malletted along the entire length of the osteotomies to complete the separation of the transplant from the mandible. **D.** After the dimensions of the alveolar ridge defect are measured, the intramembranous transplant is sculpted by a thin chisel to adapt over the osseous defect. **E.** A fixation screw stabilizes transplant. **F.** The fixation screw may be removed after a healing period of 4 months. Rigid fixation reduced transplant resorption. **G.** To evaluate the histological healing response, a 10-mm occluso-apically directed biopsy was performed at 36 weeks after transplant placement. **H.** Light microscopic examination demonstrated viable segments of bone surrounded by dense connective tissue rich in osteoblast-like cells. Specimens showed little or no infiltration of inflammatory cells. Intramembranous transplants do not produce immune reactions and seem to be incorporated by osteoclastic resorption.

The horizontal component of the vertical incision improves tissue adaptation at closure. Internally curved and cut back components provide flap flexibility and reduce tension by increasing the length of the incision.

After full-thickness flap reflection, the dimensions of the alveolar ridge defect are measured. Careful soft tissue handling and minimal trauma to the recipient site are essential to successful incorporation of the transplant (Fig. 2b–d).

At the donor site, a full-thickness mucoperiosteal incision in the anterior buccal vestibule, well beyond and parallel to the mucogingival junction, extends posteriorly to the distal aspect of the mandibular canines. The mucoperiosteal flap is elevated inferiorly to expose the mandibular symphysis. To gain access, a surgical retractor is positioned along the inferior border of the flap. Prior to osteotomy, the positions of the apices of the mandibular anterior teeth are determined. Horizontal osteotomy is performed at least 5
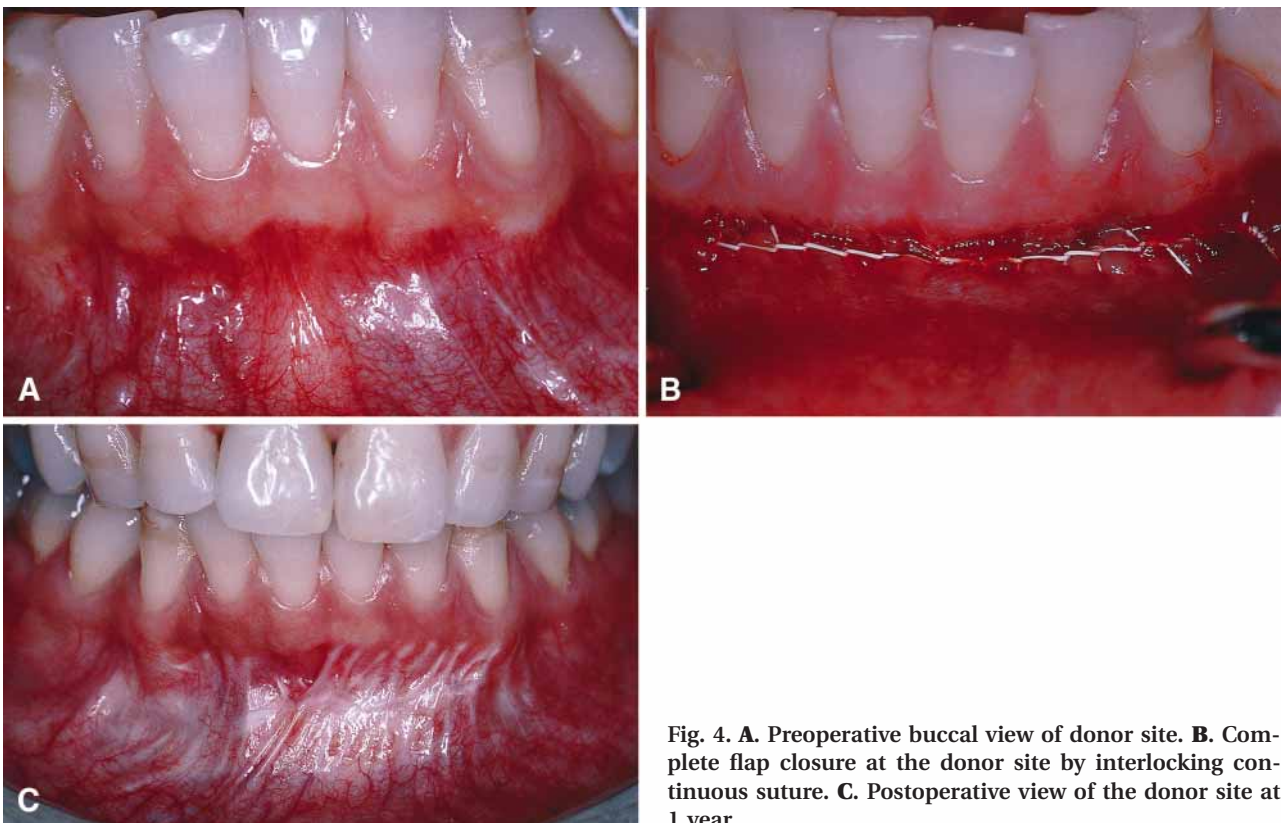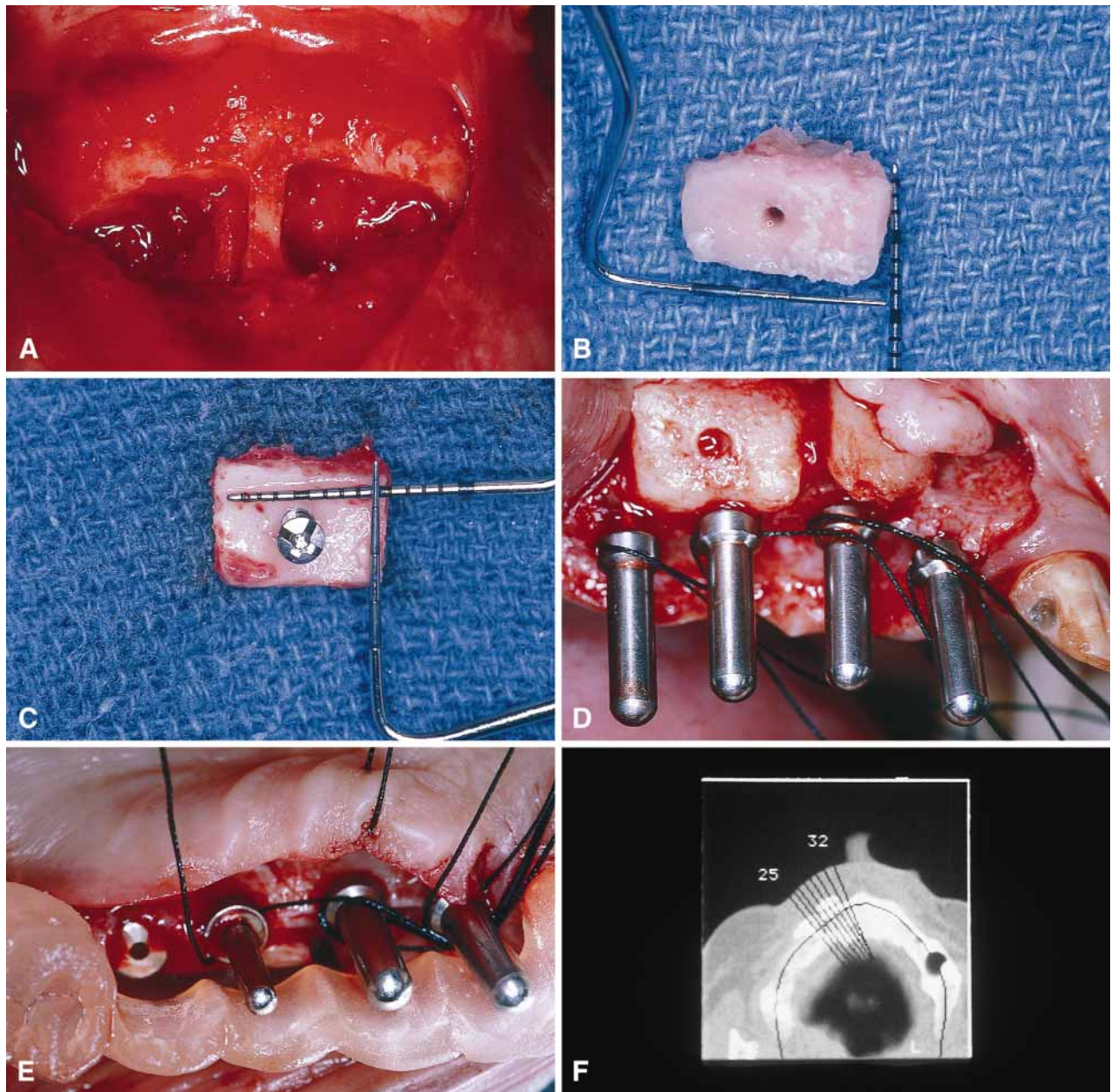

Fig. 4. **A.** Preoperative buccal view of donor site. **B.** Complete flap closure at the donor site by interlocking continuous suture. **C.** Postoperative view of the donor site at 1 year.

mm inferior to the apices of the anterior teeth. The length and the morphology of the horizontal and vertical osteotomies depend on the size requirements of the transplant. Osteotomies are performed with a small round bur under copious irrigation. Cortical osteotomies are progressively deepened until bleeding from the underlying cancellous bone is visible and desirable thickness has been achieved. A thin chisel or splitting osteotome is placed into the cuts and gently malletted along the entire length of the osteotomies to complete the separation of the graft from the mandible. Following removal of the osseous graft, sharp edges around the donor sites are smooth-

ed with a bur or surgical file. Closure of the donor site may be completed following fixation of the graft with minimal time elapsed between graft harvest and placement (Fig. 4, 5). Moist gauze is packed into the donor site prior to closure.

For the thin buccal cortical plate of the maxilla, no osseous perforation should be performed at the recipient site. However, to enhance revascularization and improve transplant incorporation, the thick buccal cortical layer of the mandibular or maxillary recipient site may be perforated with a small round bur prior to graft fixation (Fig. 3a).

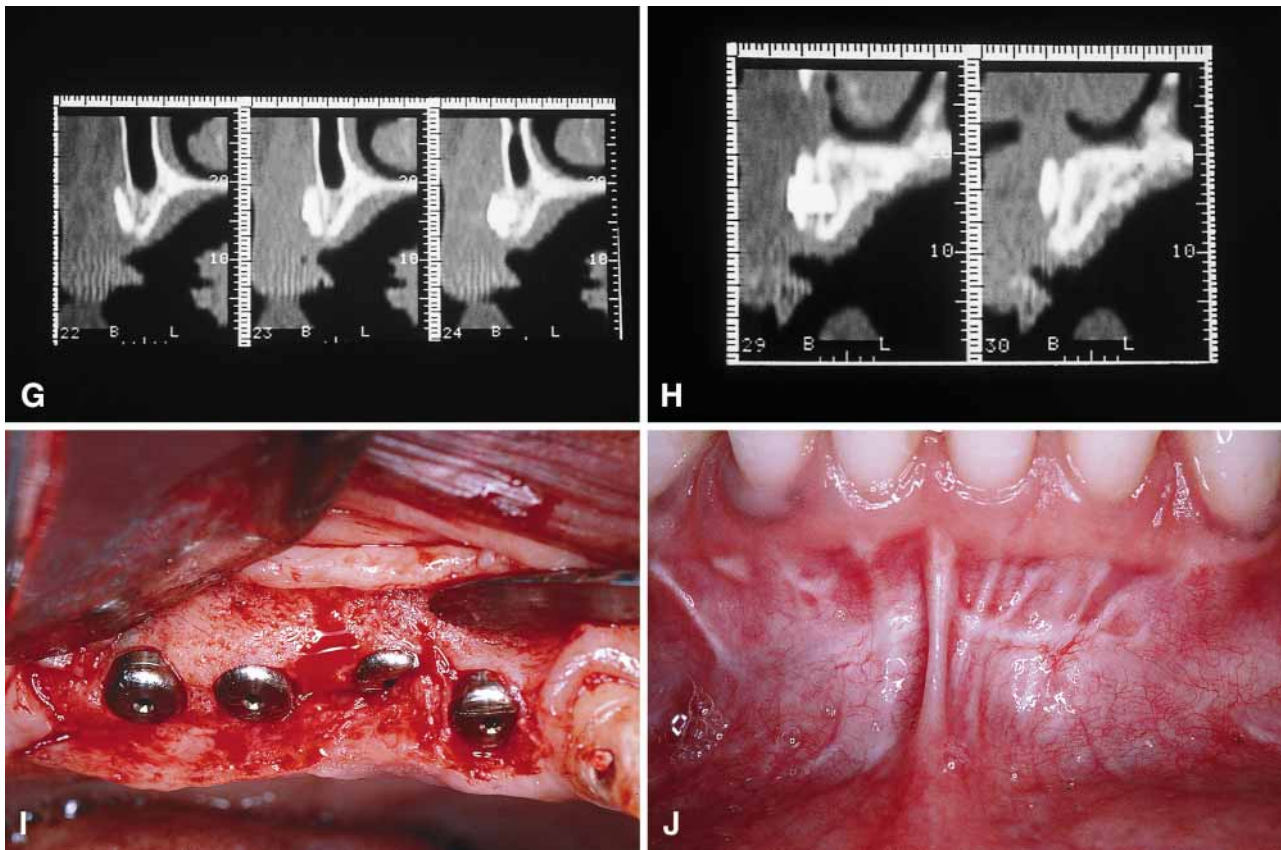The transplant is then well adapted over the oss-

Fig. 5. **A.** Surgical view of the donor site after transplant removal. Following removal, sharp edges around the donor sites are smoothed with a bur or surgical file. **B.** The length and the morphology of the transplants depend on the size requirements of the recipient site. **C.** Small-diameter fixation screws secure transplants. **D.** Operative buccal view of the maxillary arch at the time of implant placement after 4 months of transplant healing. **E.** Without osseous transplantation, implants could not be placed in a correct prosthetic position. **F.** Radiographic examination of the recipient site after osseous transplantation. Note significant improvement of the recipient site for implant placement. **G.** Radiographic examination of the recipient site after osseous transplantation. Cross-sectional view. **H.** Radiographic examination of the recipient site. Cross-sectional view. **I.** Clinical appearance at 6 months after implant placement. Transplants are fully incorporated into the maxillary bone. **J.** Clinical appearance of the donor site at 12 months.

eous defect to minimize dead space formation (Fig. 1d, 2b, 3d). The transplant is stabilized by surgical screws 1–1.5 mm in diameter, which may be removed after a healing period of 4 months (Fig. 1d, e, 3e, f). Rigid fixation reduces transplant resorption (22, 26). In fixed versus non-fixed parietal onlay transplant to mandibular cortex of 20 adult sheeps, Philipps & Rahn (26) reported greater areas of revascularization with the fixed technique.

Complete flap closure is a prerequisite for successful treatment (Fig. 2c). The type of provisional prosthesis used during the healing period is also critical to optimal healing. The design of the provisional restorations should minimize postsurgical irritation and pressure on the soft tissue.

Transplant healing process

Vascularization

Rapid vascularization of the transplant is a prerequisite to successful osteogenesis (2, 12).

Cancellous transplants may be entirely penetrated by blood vessels in 2 days and completely revascularized within 2 weeks. Cortical transplants may be penetrated by blood vessels in 6 days and completely revascularized in 1–2 months (14, 21).

End-to-end vascular anastomosis occurs in the cancellous transplant. Osteoclastic activity and vascular infiltration of Volkmann and Haversian canals occur in the cortical transplant (13).

Neo-osteogenesis by osteoblastic activity (phase 1)

Osteoblasts surviving transplantation proliferate and produce osteoid matrix. Neo-osteogenesis would be proportional to osteoblast viability and density. Neo-osteogenesis is called phase 1 of the healing process (2, 12–14, 21).

Osteoinduction by osteoclastic secretion of promoter proteins (phase 2)

Phase 2 or osteoclastic resorption of the osteoid matrix and osteoclastic secretion of promoter proteins characterize osteoinduction (11, 13, 14). Promoter proteins such as bone morphogenetic proteins or osteogenin induce transformation of pluripotent mesenchymal stem cells into osteoblasts. More than 40 bone morphogenetic proteins have been isolated. *In vitro* studies using multipotent progenitor cells, osteoprogenitor cells, osteoblasts, chondroblasts, and osteosarcomatic cells have shown that bone morphogenetic proteins induce or inhibit cell proliferation depending on cell types and culture conditions. The highest concentrations of bone morphogenetic proteins are measured in dense intramembranous transplants of the mandibular symphysis, ramus and calvaria (11, 29).

Osteoinduction forms a new matrix capable of organizing Haversian systems. At 4–6 months, the new matrix withstands functional loads by remodeling. Osteoinduction is a slow process that begins several weeks after transplantation and continues for up to 2 years.

The osteoinductive potential of matrix is a peculiar characteristic of mineralized tissue. Collagenous matrices such as skin, aorta, or tendons do not express this biological activity. Also, geometry of the extracellular matrix plays a fundamental role in osteoinduction. Matrix pretreatment by substances such as polyanions (heparin, dextran sulfate and polyvinyl sulfonate) that alter the geometry can inhibit osteogenic cellular differentiation (14, 16, 29). Alteration of the charge characteristics of the matrix by chemical modification such as acetylation and carbodimethylation can also inhibit differentiation.

Light microscopic observations

The histological healing pattern has been clarified in studies on primates (14). Cortico-cancellous bone was onlay transplanted to the mandibular cortex of monkeys. The cancellous site of transplants faced the cortical plate of recipient sites.

At 1 week, inflammatory infiltrates and edema surrounded transplants. Light microscopic observations showed a rim of osteoblasts and osteoid-like tissue at the junction of transplant-cortex and active osteoclasts at the mandibular cortex. The transplant was highly revascularized (14).

At 2 weeks, light microscopic observations showed a heavier rim of osteoblasts and new trabecular formation superior to the transplant. Osteoclastic activity at the mandibular cortex was associated with vascular proliferation from the medullary portion of the mandible through the cortex to the transplant (14).

At 1 month, inflammation and edema decreased. Resorption was detected around the transplant. Osseous trabeculation superior to the transplant began from the periosteal side of the soft tissue. An exuberant vascular response was present (14).

At 2 months, the transplant could not be distinguished easily from the mandibular cortex. Newly formed cortex was composed of immature lamellar patterns and irregular trabeculae (14).

At 3 months, a thicker cortical plate was observed. Irregular trabeculae were still evident. Osteoclasts and osteoblasts were detected occasionally (14).

At 6 months, the transplant was fully incorporated into the mandibular cortex. However, the lamellar pattern of the newly formed bone was still immature (14).

Biological and molecular events

The models usually used to study *in vitro* osteogenesis are summarized in Table 2.

Osteoinduction by osteoclastic secretion of promoter proteins (phase 2) includes chemotaxis, mitosis and differentiation.

Table 2. Models usually used to study *in vitro* osteogenesis

Model	Advantages
Intact calvaria	Normal tissue viable in the absence of serum Allows the study of multiple parameters of bone formation
Normal calvarial cell suspensions	Normal cells enriched in osteoblasts viable in the absence of serum Allows the study of multiple parameters of bone formation
Osteosarcoma cell lines	Continuous single cell line with osteoblastic properties

Source: Canalis (11).

Chemotaxis, the first event in the process of osteo-induction, is the cellular migration in response to a chemical gradient such as fibronectin. After osseous transplantation, fibronectin, a plasma protein of 450 kDa, binds avidly to the transplant matrix. Fibronectin has an affinity for collagen, fibrin and heparin, the major components in the site of skeletal trauma. Fibronectin is mitogenic as well (11).

Studies performed on rats demonstrated that the extracted fraction of proteins of 60 kDa expresses a potent chemotactic activity. Fractions of less than 50 kDa induce *in vivo* neo-osteogenesis, promote fibroblastic growth in culture and are active on embryonic skeletal muscle by transformation of muscular mesenchymal cells into chondrocytes (29, 33, 38).

The mitotic phase is the induced proliferation of newly attached multipotent mesenchymal stem cells followed by cellular differentiation.

Table 3 summarizes the cellular events and biochemical processes after implantation. Although the description focuses on endochondral osseous induction, the biological process shares similarities with endomembranous osseous induction (29).

Growth factors

Growth factors such as osteocalcin, bone-derived growth factor, bone morphogenetic proteins and platelet-derived growth factors play fundamental roles in cell replication and differentiation. However, their role in the incorporation of the osseous transplant is unclear (15).

Transforming growth factors (α, 1 and β) stimulate cell replication in skeletal and nonskeletal tissues but inhibit differentiated function. Fibroblast growth factor stimulates cell replication in both cartilage

Table 3. Cellular events and biochemical processes after implantation

| Time after implantation	Cellular events	Molecular processes
1 min	Blood clot formation Platelet release	Fibrin network formation Release of platelet-derived growth factors Binding of fibronectin to implanted materials
1 h	Arrival of polymorphonuclear leukocytes by chemotaxis	Release of proteolytic enzymes such as collagenases and elastases Release of collagenous peptides
3–18 h	Accumulation of polymorphonuclear leukocytes Adhesion of cells	Limited proteolysis and release of chemotactic factors for fibroblast
Day 1	Chemotaxis of fibroblast and cell attachment to the implanted extracellular matrix	Release of peptides of fibronectin Increased cell motility Role of microtubules and microfilaments
Day 2	Continuation of chemotaxis for fibroblast Signal transduction from matrix to cell surface	Initiation of protein and nucleic acid synthesis Release of growth factor
Day 3	Cell proliferation	^{3}H-thymidine incorporation into DNA Increase in ornithine decarboxylase activity Type III collagen synthesis
Day 5	Differentiation of chondroblasts	Increase in $^{35}SO_4$ incorporation in proteoglycans
Day 7	Chondrocytes, synthesis and secretion of matrix	Type II collagen synthesis Cartilage specific proteoglycans
Day 9	Hypertrophy of chondrocytes Calcification of cartilage matrix Vascular invasion	Increase in ^{45}Ca incorporation and alkaline phosphatase activity Type IV collagen synthesis Laminin and factor VIII in blood vessels
Days 10–12	Osteoblasts Bone formation and mineralization	Type I collagen synthesis Bone proteoglycan synthesis Peak in ^{45}Ca incorporation and Alkaline phosphataseactivity
Days 12–18	Osteoclasts Bone remodeling and dissolution of the implanted matrix	Increase in lysosomal enzymes (acid phosphatase, aryl sulfatase, beta glucuronidase) Upswing in accumulation of gamma carboxyglutamic acid containing protein (osteocalcin) Release of collagenase and protease
Day 21	Bone marrow differentiation	Increase in ^{59}Fe incorporation into heme Accumulation of lysozyme Type III collagen synthesis

Source: Reddi et al. (21).
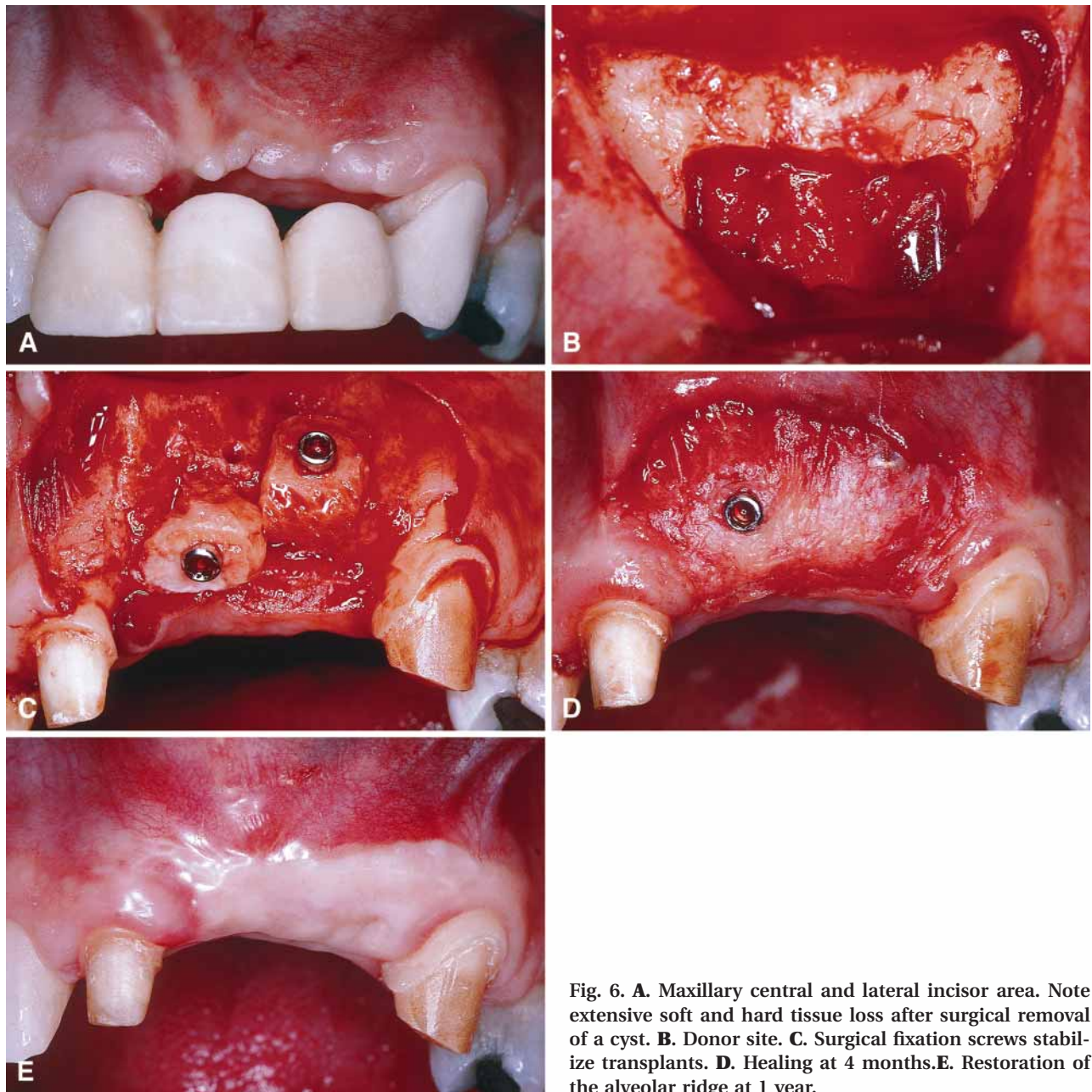
Fig. 6. **A.** Maxillary central and lateral incisor area. Note extensive soft and hard tissue loss after surgical removal of a cyst. **B.** Donor site. **C.** Surgical fixation screws stabilize transplants. **D.** Healing at 4 months.**E.** Restoration of the alveolar ridge at 1 year.

and bone culture systems but inhibits osteoblastic function. Platelet-derived growth factor, released during the process of clotting, stimulates cell replication and generalized protein synthesis by differentiated cells. Insulin-like growth factors (I and II), having structural homologies with insulin, are the only systemic factors that simultaneously stimulate bone cell replication and differentiation (11).

Osseous growth is also regulated by local peptides. Bone-derived growth factors (I and II) stimulate osseous collagen formation, osseous DNA synthesis and cell replication (11, 20). Osteonectin and osteocalcin binding to hydroxyapatite crystals suggest a role in osseous mineralization for these proteins (27, 40). Bone morphogenetic proteins isolated from osseous matrix induce differentiation of mesenchymal-type perivascular cells into cartilage and then into bone (11). After transplantation, collagen and non-collagenous bone proteins play a role in osseous physiology by maintaining the equilibrium between osseous formation and resorption. Monokines (interleukin-1 secreted by macrophages, prostaglandins secreted by normal bone and osteosarcoma cells, etc.) are potent stimulators of osseous resorption (11).
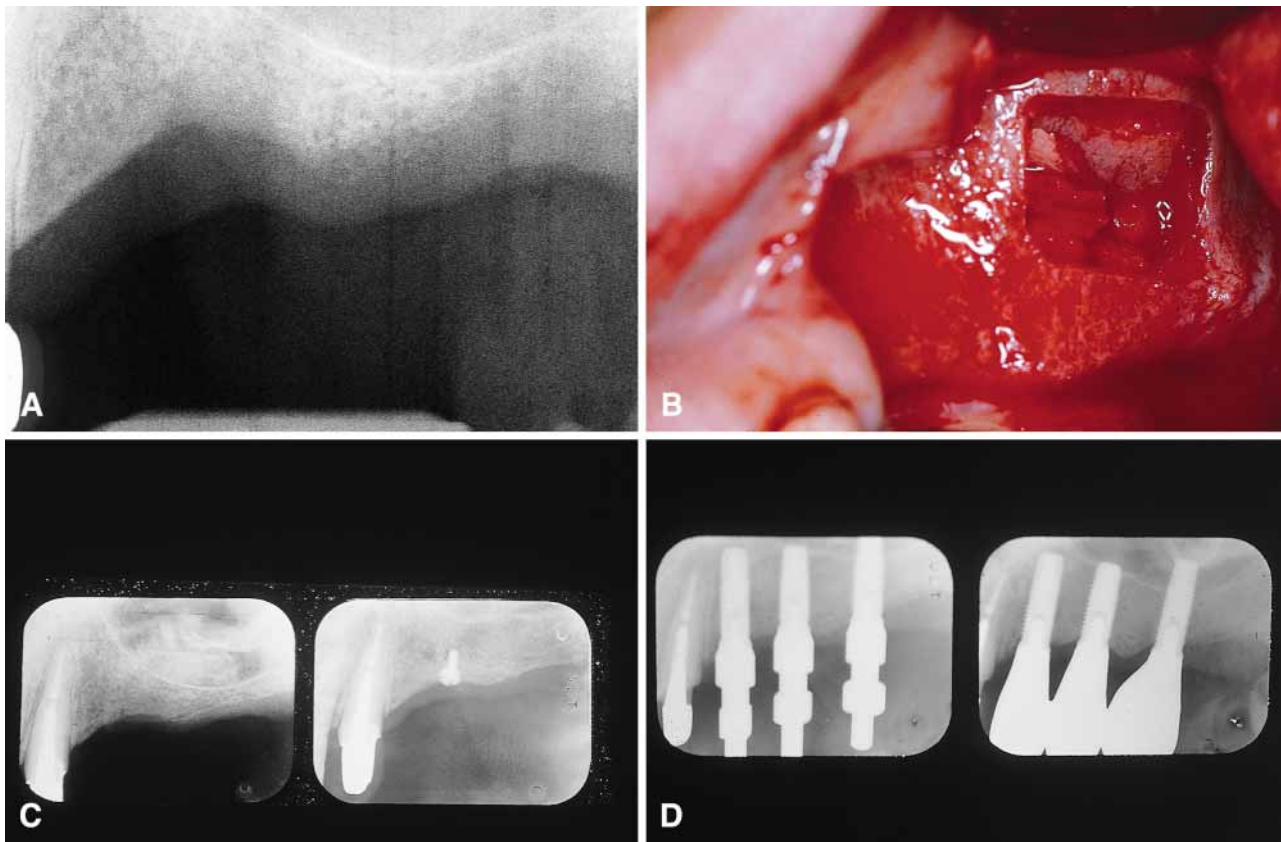
Fig. 7. **A.** Radiographic examination of the maxillary posterior sextant. Note significant osseous deficiency. **B.** Surgical appearance after sinus elevation procedure using mandibular cortical transplant. Only cortical bone was used. **C.** Radiographic examination of the recipient site after osseous transplantation. Note significant improvement of the recipient site for implant placement. **D.** Radiographic examination of the recipient site after implant placement.

Donor site healing process

The potential of re-harvesting an autogenous osseous transplant using the same donor site has been evaluated in an animal study on the canine model (24). The complete replacement of the cancellous bone was completed after 1 year. Healing in canines is twice as fast as in humans. Therefore, donor sites in human may be a potential source of additional autogenous osseous transplant material after 24 months (24).

When a large volume of intramembranous autogenous bone has been transplanted, the donor site may have to be grafted as well. Intraoral sources of osseous graft material include the maxillary tuberosity, angle of the mandible, ramus and exostoses.

Conclusion

Intramembranous autogenous osseous transplants, including the mandibular symphysis, angle of the mandible, ramus, maxillary tuberosity and intraoral exostoses, are the "gold standard" in the restoration of intraoral osseous volume.

Intramembranous transplants do not produce immune reactions and are incorporated by osteoclastic resorption with a shorter healing period compared with other methods of osseous repair. Intramembranous autogenous osseous transplants and intraoral recipient sites share embryological ectomesenchymal origin, intramembranous ossification (16, 36, 44) and biochemical and biological similarities that enhance transplant revascularization and incorpor-

ation potential. The highest concentrations of promoter proteins such as bone morphogenetic proteins or osteogenin are found in the mandibular symphysis, ramus and calvaria. The mandibular symphysis is a convenient source and provides a dense cortical quality transplant. The thick cortical layer of the transplant prevents or reduces resorption (11, 29).

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