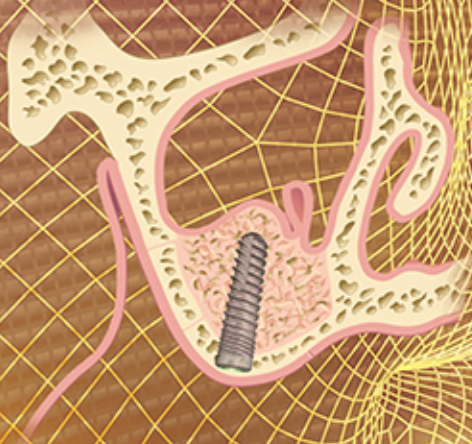
MAXILLARY SINUS BONE GRAFTING

A Picture Atlas Featuring Over 50 Complete Step-by-Step Cases



Arun K. Garg, DMD
Gustavo Mugnolo, DDS, PhD

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GARG MULTIMEDIA GROUP, INC.

Garg Multimedia Group, Inc.
1840 NE 153rd Street
North Miami Beach, FL 33162

Edited by Dr. Arun K. Garg and Dr. Gustavo Mugnolo
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CHAPTER

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CHAPTER

1 Bone Biology and Physiology for Dental Implantology

The dental implant clinician must have a thorough understanding of bone structure and metabolism as well as knowledge of the process of osseointegration when bone grafts and implants are placed. A short example should illustrate the need for this understanding and knowledge: Differences in the metabolism and aging of endochondral and intramembranous bone present especially important concerns for the dental and maxillofacial surgeon.1 Endochondral ossification, the type of bone development which begins embryonically, also occurs during bone healing after a fracture, so it is possible that the dental patient's age is a factor in the rate of bone healing, particularly since fracture healing is dependent not only on tissue revascularization but also on cell differentiation and proliferation. An additional age-related healing factor directly affects the alveolar (primarily the mandible) bone, whose formation occurs intramembranously.

Unquestionably, such bone-related clinical features of skull and jaws are discussed generally (and in some cases with specific references to dental and maxillofacial clinical practice) in the first section of this current study, "The Human Skeleton: An Overview." This first section covers bone cells and metabolism, bone's macro/microscopic and molecular structure, and bone modeling and remodeling. By contrast, the essay's second section, "Dental Implantology: Bone Structure, Metabolism, and Physiology," presents information specifically related to oral implantology: Bone formation/modeling with bone grafts, osseointegra-

tion of dental implants, and autologous blood concentrates.

The hope is that this study's general overview of the characteristics of human bone will provide the necessary background and context for a more specialized discussion, understanding, and application of dental implantology practices so that the dental clinician who specializes in this area will have a better appreciation of the role that bone plays in successfully placing dental implants.

THE HUMAN SKELETON: AN OVERVIEW

The entire adult skeleton exists in a dynamic state, continually degenerating and regenerating by the coordinated action of osteoclasts and osteoblasts (Figure 1-1). Bone is a living tissue that serves two primary functions: structural support and calcium metabolism. The bone matrix is composed of an extremely complex network of collagen protein fibers impregnated with mineral salts that include mostly calcium phosphate, far less calcium carbonate, and very small amounts of calcium fluoride and magnesium fluoride. The minerals in bone are present primarily in the form of hydroxyapatites. Bone also contains small quantities of non-collagen proteins embedded in its mineral matrix, including the all-important family of bone morphogenetic proteins (BMPs). Coursing through the bone is a rich vascular network that provides perfusion to the viable cells as well as the network of nerves (Figure 1-2). Sufficient amounts of proteins and minerals must be present in the body for normal bone structure.

Because of its unique architecture, bone is mass-efficient: Maximal strength is achieved with minimal mass (Figure 1-3). In humans, bone mass reaches its maximum level approximately ten years after the end of linear growth. This level normally remains fairly constant since bone is continually deposited and absorbed throughout the skeleton until sometime in the fourth decade of life when bone mass begins to gradually decline. Although the reasons are not clearly understood, this decline is a result of an ongoing net loss that begins to occur in the bone remodeling process. By age eighty, both men and women typically have lost about half of their maximum bone mass value. Humans reach peak bone mineral density in their thirties, though it is lower in women than in men and in whites than in blacks. Women lose an estimated third of their cortical bone and half of cancellous bone as they age while men lose only two-thirds of these amounts. Bone deemed unnecessary by the body (for example, atrophy and bone loss in paraplegic patients) is also lost during a shift in the absorption-deposition balance in bone remodeling; in addition, turnover may be a response to metabolic reactions.

Bone Cells

Three main types of cells are involved in bone metabolism and physiology: osteoblasts, osteocytes, and osteoclasts. Osteoblasts, which are involved in building bone, are located in two general areas. These cells deposit bone matrix (Figure 1-4) and are frequently referred to as either endosteal osteoblasts, periosteal osteoblasts, or periosteal osteoblasts. Periosteal osteoblasts are present on the outer surfaces of the bones beneath the periosteum, while endosteal osteoblasts line the vascular canals within bone. Mature osteoblasts are responsible for producing the proteins of bone matrix. Indeed, the cytoplasm of osteoblasts is intensely basophilic, suggesting the presence of ribonucleoproteins that are related to the synthesis of these protein components. Bone deposition continues in an active growth area for several months, with osteoblasts laying down new bone in successive layers of concentric circles on the inner surfaces of the cavity in which they are working. This activity continues until the tunnel is filled with new bone to the point that the new growth begins to encroach on the blood vessels running through it. In addition to mineralizing newly formed bone matrix, osteoblasts also produce other matrix constituents, such as phospholipids and proteoglycans, which may also be important in the mineralization process. During osteogenesis, the osteoblasts secrete growth factors, including transforming growth factors, such as transforming growth factor-beta (TGF-β), BMPs, platelet-derived growth factor (PDGF), and insulin-like growth factors (IGFs), which are stored in bone matrix. Some recent research suggests that osteoblasts may even act as helper cells for osteoclasts during normal bone resorption, possibly by preparing the bone surface for their attack.[2,3] However, further study is needed to clarify this possible role.

When osteoblasts have successfully formed bone matrix and then become embedded in it, they transform into osteocytes (Figure 1-1b). Osteocytes are the most abundant bone cells, and they communicate with each other and with cells on the bone surface via dendritic processes encased in canaliculi. Osteocytes have a slightly basophilic cytoplasm, the prolongations of which extend from the osteocyte through a network of fine canaliculi that emerge from the lacunae. During bone formation, these prolongations extend beyond their normal limit, creating direct continuity with adjacent osteocytes lacunae and with the tissue spaces. Fluid in these spaces mixes with fluid from the canaliculi; this mixing appears to allow an exchange of metabolic and biochemical messages between the bloodstream and osteocytes. In mature bone, there is almost no extension of these prolongations, but the canaliculi continue to function as a means of messenger exchange. This mechanism allows the osteocytes to remain alive, regardless of the calcified intercellular substance surrounding them. However, this duct system does not function if it is located more than 0.5 mm from a capillary, which may explain the abundant blood supply in bone

through capillaries that run through the Haversian systems and Volkmann canals. Osteocytes have also been shown to express TGF-β and possibly other growth factors. Weightbearing loads may influence the behavior of bone remodeling cells located on bone surfaces by their effects on the osteocytes buried within the bone, which subsequently release TGF-β into the canalicular system. Additionally, osteocytes may play a role in transporting calcium through the bone.

Osteoclasts are the cells responsible for bone resorption, and their activity is controlled by parathyroid hormone. Osteoclasts are fused monocytes that histologically appear as large, multinucleated giant cells (containing as many as 50 nuclei). They are located in shallow excavations (Howship lacunae) along the mineralized bone surfaces. A specific area of their cell membrane forms adjacent to the bone surface to be resorbed. This area, known as the ruffled border, is formed by villus-like projections that the osteoclasts send out toward the bone. It consists of folds and invaginations that allow intimate contact between the cell membrane and the bone surface (Figure 1-1b). Bone resorption occurs in the ruffled border as the villi secrete proteolytic enzymes that digest or dissolve the organic bone matrix and acids that cause dissolution of the bone cells. Via phagocytosis, osteoclasts also absorb minute particles of bone matrix and crystals, eventually dissolving them and releasing the products into the bloodstream. In adults, osteoclasts are usually active on less than 1% of bone surfaces at any one time. They typically exist in small but concentrated masses. Once a mass has developed, it usually dissolves the bone for about three weeks, creating a tunnel that ranges from 0.2 to 1.0 mm in diameter and is several millimeters long. After local bone resorption is complete, the osteoclasts disappear, probably by degeneration. Subsequently, the tunnel is invaded by osteoblasts, and the bone formation segment of the continuous remodeling cycle begins again.

In addition to the three main types of bone cells, there is a fourth type, the bone-lining cell. These cells are similar to osteocytes in that they are "retired" osteoblasts–in other words, osteoblasts that do not become embedded in newly formed bone but instead adhere to the outer bone surfaces when formation halts. Bone-lining cells become quiescent and flattened against the bone surface, but they do not form a contiguous gap-free barrier. They maintain communication with osteocytes and with each other via gap-junctioned processes, and they also appear to maintain their receptors for hormones such as parathyroid hormone and estrogens. As with osteocytes, bone-lining cells are thought to play a role in transferring mineral into and out of bone and in sensing mechanical strain. They may also initiate bone remodeling in response to various chemicals or mechanical stimuli.

Bone Metabolism

Bone is the body's primary reservoir of calcium. Its tremendous turnover capability allows it to respond to the body's metabolic needs and to main-

tain a stable serum calcium level. Calcium has an essential life-support function. It works in conjunction with the lungs and kidneys to help maintain the body's pH balance by producing additional phosphates and carbonates. It also assists in the conduction of nerve and muscle electrical charges, including those involving the heart (Figure 1-1b).

Bone structure and mass throughout the body, including the structure and mass of bone in the skull and jaw, are directly affected by the body's metabolic state. Faced with unmet calcium requirements or certain diseases, the structural integrity of bone may be altered and even compromised. Consider the bone structure of postmenopausal women. In response to decreased estrogen hormone in the system, bone mass begins to dwindle, and the interconnections between bone trabeculae are lost. Because normal interconnections are crucial for making bone biomechanically rigid, the decrease in bone leads to an increase in fragility. This is an important phenomenon in dental implantology and related bone grafting because it would seem to suggest that declining estrogen levels would increase the risk of implant failure.4 However, recent studies suggest that neither osteoporosis5 nor menopausal status6 in and of themselves are contraindications for dental implant placement.

The effects of a disrupted balance in bone remodeling are illustrated by Albers-Schoenberg, or "marble bone" disease, which involves defective osteoclasts. Because these osteoclasts do not resorb the existing bone matrix and liberate bone morphogenetic proteins, new bone is not formed, resulting in avascular and acellular bone (essentially, old bone) that is brittle and thus fractures easily and frequently becomes infected. Other diseases associated with bone remodeling abnormalities include cancer, primary hyperparathyroidism, and Paget disease. Although these disorders are common, in most cases little is known about what mechanisms are responsible for controlling normal bone remodeling or how it is coordinated and balanced. Metabolic-hormonal interactions play a crucial role in maintaining bone structure. Most importantly, they help to maintain the coupled cycle of bone resorption and bone apposition through BMP. As previously mentioned, when osteoblasts form bone, they also secrete BMP into the mineral matrix. This acid-insoluble protein resides in the matrix until it is released during osteoclastic resorption. The acid insolubility is an evolutionary mechanism by which the pH of 1 created by osteoclasts is able to dissolve bone mineral without affecting BMP. Once released, BMP binds to the cell surface of undifferentiated mesenchymal stem cells, where it causes a membrane signal protein to become activated with high-energy phosphate bonds. This, in turn, affects the gene sequence in the nucleus, causing expression of osteoblast differentiation and stimulation of new bone production. A disruption of this process may be at the root of osteoporosis. Of current research interest is the therapeutic potential of applying BMPs directly to a healing site to induce bone formation. Some researchers suggest that in the future, this biologic material may

replace or assist bone grafts in restorative therapy.7

Normally, about 0.7% of the human skeleton is resorbed and replaced by new, healthy bone each day (Figures 1-1b and 1-2b). Therefore, normal turnover of the entire skeleton occurs approximately every 142 days. With aging and metabolic disease states, there may be a reduction in the normal turnover process and thus an increase in the average age of functional bone. This raises the risk for fatigue damage of old bone, compromised bone healing, failed implant integration, and loss of implant osseointegration. Thus, it is important for dental clinicians to recognize that a compromised status must be considered before treatment planning because its effects may not be revealed until the clinician attempts to place implants or until the implants have been in place for some time.

Macroscopic Structure of Bone

The human skeleton is composed of two distinct kinds of bone based on porosity: dense cortical tissue and spongy cancellous tissue (Figure 1-5). In principle, the porosity of bone could vary continuously from 0% to 100%; however, most sites are either of very low or very high porosity. In most cases, both cortical and cancellous tissues are found at every bone site, but their quantity and distribution vary. The non-mineralized spaces within bone contain marrow, a tissue consisting of blood vessels, nerves, and various cell types. Marrow's chief function is to generate the principal cells present in blood; it is also a highly osteogenic material that can stimulate bone formation if placed in an extracellular skeletal location, as with bone grafting in the dental area.

Cortical or compact bone, which comprises the vast majority of total bone in the body, is found in the shafts of long bones and forms a shell around vertebral bodies and other spongy bones (Figure 1-6). This tissue is organized in bony cylinders consolidated around a central blood vessel, called a Haversian system. Haversian canals, which contain capillaries and nerves, are connected to each other and to the outside surfaces of the bone by short, transverse Volkmann canals.

Trabecular (cancellous) bone, which comprises about 15% of the body's total bone, is found in cuboidal and flat bones and in the ends of long bones. Its pores are interconnected and filled with marrow. The bone matrix is in the form of plates (called trabeculae) arranged in a varied fashion; sometimes they appear to be organized into orthogonal array, but often they are randomly arranged. The medullary cavities are filled with marrow, which is red when there is active production of blood cells or a reserve population of mesenchymal stem cells, and yellow when aging causes the cavity to be converted into a site for fat storage.

Except for the articular surfaces, the

outer surface of bone is covered with periosteum, which forms a boundary between the hard tissue and its soft tissue covering. It is also the site of considerable metabolic, cellular, and biomechanical activities that modulate bone growth and shape (Figure 1-7). The periosteum is composed of two layers of specialized connective tissue. The outer fibrous layer, mainly formed from dense collagenous fibers and fibroblasts, provides toughness while the inner cellular (cambium layer), which is in direct contact with bone, contains functional osteoblasts. The medullary cavities and spaces are covered by endosteum, a very thin and delicate membrane consisting of a single layer of osteoblasts. The endosteum is architecturally similar to the cambium layer of the periosteum because of the presence of osteoprogenitor cells, osteoblasts, and osteoclasts.

Microscopic Structure of Bone

At the microscopic level, there are four types of bone: woven, composite, lamellar, and bundle. Woven bone plays a principal role in healing because it forms very quickly (approximately 30 to 60 mm/day). As a result, it develops in a very disorganized fashion, without lamellar architecture or Haversian systems. Thus, it is quite soft, biomechanically weak, and short-lived. On the plus side, however, woven bone can become more highly mineralized than lamellar bone, a fact that, mechanically speaking, may help to compensate for its lack of organization. During healing, woven bone is often referred to as phase I bone. It is fairly quickly resorbed and replaced with more mature lamellar bone (phase II bone). Composite bone refers to the transitional state between phase I bone and phase II bone, in which can be detected a woven bone lattice filled with lamellar bone. Lamellar bone is the most abundant, mature, load-bearing bone in the body. This type of bone forms slowly (approximately 0.6 to 1 mm/day) and thus has well-organized collagen protein and mineralized structure. Lamellar bone consists of multiple oriented layers. Bundle bone is the principal bone found around ligaments and joints, and it consists of striated interconnections with ligaments.

Bone's mechanical viability and its fragility depend to a certain degree on the structure and microstructure of the cortical bone compartment. Beyond bone mineral density and bone mineral content, additional features of cortical bone contribute to whole bone's resistance to fracture. Structural properties of cortical bone most commonly employed as surrogate for its mechanical competence include thickness of the cortex, cortical cross-sectional area, and area moment of inertia.

But microstructural properties—such as cortical porosity, crystallinity, or the presence of microcracks—also contribute to bone's mechanical compe-

tence. Microcracks, in particular, not only weaken the cortical bone tissue but also provide an effective mechanism for energy dissipation. Bone is a damageable, viscoelastic composite, living material capable of self-repair. As a result, it demonstrates a complex series of mechanical properties. For the implantologist, a direct correlation exists between the science of cortical bone and microcracks/microdamage and the kinds of damage that can occur when tapered and cylindrical implants are placed after pilot drilling.8 Implant osteotomy preparation that avoids microdamage can directly affect initial implant stability and bone healing/osseointegration.[9]

One feature largely disregarded in the diagnosis of bone diseases and fracture risk assessment is the contribution of cortical bone quantity and quality. Cortical bone carries a considerable share of the total load of the skeleton. Biomechanical studies demonstrate that the structural behavior of whole bone specimens is highly determined by the contribution of cortical bone. In biomechanics, a distinction is usually made between the mechanical (material) behavior of bone tissue and the mechanical (structural) behavior of the entire bone. Bone's mechanical competence reflects both the geometry (size and shape) and the intrinsic material properties (elasticity, strength, and toughness). Because of the complexity of the bone failure mechanism, it is not certain which properties account for bone fragility. Toughness or energy to failure, a tissue property pertaining to the capability of bone tissue to absorb energy during the failure process, is likely a dominant determinant of fracture risk. From a mechanical perspective, it is quite obvious that the rigidity and strength of a structure is determined not only by the amount of material but even more importantly by the arrangement of the material in space.

Haversian canals and resorption cavities in cortical bone produce a porous bone tissue with pore diameters ranging from a few to up to several hundred micrometers. Morphometry and biomechanical testing have perceived strong correlations between intracortical porosity and cortical bone material properties. The number and size of the pores determine intracortical porosity, which accounts for about 70% of elastic modulus and 55% of yield stress.10 Local BMD measurements in cortical bone specimens corroborate these findings.[11] Fracture toughness also decreases with increasing porosity possibly by reducing the available area for the propagation of microcracks.[12]

Molecular Structure of Bone

At the molecular level, bone is composed of collagen (primarily type I), water, hydroxyapatite material, and small amounts of proteoglycans and noncollagenous proteins. It is a cross-

linked collagen matrix with a three-dimensional multiple arrangement of matrix fibers. The orientation of the collagen fibers determines the mineralization pattern. In this way, bone adapts to its biomechanical environment and projects maximal strength in the direction receiving compressive loads. Collagen gives bone tensile strength and flexibility and provides a place for the nucleation of bone mineral crystals, which give bone its rigidity and compressive strength.

The intercellular bone substance has an organized structure. The organic portion occupies 35% of the matrix and is primarily formed by osteocollagenous fibers, similar to collagen fibers in connective tissue. These are joined together by a cement-like substance that consists primarily of glucoaminoglycan (protein-polysaccharide). The inorganic component of bone comprises 65% of bone weight and is localized only in the interfibrous cement. The minerals in bone consist mainly of hydroxyapatite crystals, which form deposits along the osteocollagenous fibers. It also contains other substances, such as carbonate, fluoride, other proteins, and peptides. Some of these materials are governed by the body fluid composition and affect the solubility of bone mineral.

Other components, such as BMP, regulate how bone is laid down and maintained. Bone matrix has sequential lamellae that vary in thickness from 300 to 700 μm. These layers are the result of rhythmic and uniform matrix deposition. Also characteristic is the pattern of fibers within each layer, which are parallel and exhibit a spiral orientation that changes between layers so that the fibers in one layer run perpendicular to those in the adjacent layer. This pattern creates the distinguishable bone layers.

Bone Modeling and Remodeling

As noted above, bone is continually being deposited by osteoblasts and absorbed by osteoclasts at active sites in the body. In adults, a small amount of new bone is continually being formed by osteoblasts, which work on about 4% of all surfaces at any given time. Although many orthopedists and bone scientists refer to both processes as remodeling, it is important to note that bone modeling involves two different processes in osseous repair. Bone modeling typically refers to the sculpting and shaping of bones after they have grown in length. This process involves the independent, uncoupled actions of osteoclasts and osteoblasts, so bone is resorbed in some areas and added in others. Bone modeling can also be controlled by mechanical factors, for example, during orthodontic tooth movement, in which the application of force causes the bone to resorb on the tooth surface, new bone to form on the opposite surface, and the tooth to move with the surrounding bone

rather than through the alveolus. Bone modeling can change both the size and shape of the bones. Bone remodeling, on the other hand, refers to the sequential, coupled actions by these two types of cells. It is a cyclical process that usually does not change the size or shape of bones. Bone remodeling removes a portion of old bone and replaces it with new bone.

Unlike bone modeling, which slows substantially after growth stops, bone remodeling occurs throughout life (although its rate also slows somewhat after growth). Bone remodeling also occurs throughout the skeleton in focal, discrete packets that are distinct in location and chronology. This characteristic of remodeling suggests that the activation of the cellular sequence responsible for bone remodeling is controlled locally, possibly by an autoregulatory mechanism, such as autocrine or paracrine factors generated in the bone microenvironment.

Bone modeling also occurs during wound healing (for example, during the stabilization of endosseous implants) and in response to bone loading. Unlike bone remodeling, bone modeling does not have to be preceded by resorption. The activation of cells that resorb and of those that form bone can occur on different surfaces within the same bone. In addition, bone modeling may also be controlled by growth factors, as in bone healing, grafting, and implant osseointegration. Whether bone is being modeled or remodeled, it is deposited in proportion to the compressional load it must carry. For instance, the bones of athletes become considerably heavier than those of non-athletes. Likewise, a person with one leg in a cast who continues to walk using only the opposite leg will experience a thinning of the unused leg bone.

Continuous physical stress stimulates osteoblastic activity and calcification of bone. Bone stress also determines the shape of bones in some circumstances. It has been theorized that bone compression causes a negative electrical potential in the compressed area and a positive electrical potential elsewhere in the bone. Minute amounts of electric current flowing in bone have been shown to cause osteoblastic activity at the negative end of the current flow, which may explain increased bone deposition in compression sites. This effect is the basis of studies on the use of electrical stimulation to promote bone formation and osseointegration, though further research is needed to support claims of benefit.[13]

DENTAL IMPLANTOLOGY:
Bone structure, metabolism, and physiology

When placing implants in the mandible or maxilla, clinicians must understand the process of bone remodeling, the different types of bone, and how

these factors can affect the integration of osseous dental implants. Approximately 0.7% of a human skeleton is resorbed daily and replaced by new healthy bone. With aging and metabolic disease states, the normal turnover process may be reduced, resulting in an increase in the mean age of the present bone. This increase can affect the placement and integration of implants.

Bone Formation and Modeling with Bone Graft Materials

In most cases, the goal of placing bone grafts in dentistry is to regenerate lost tissue as well as simply to repair or fill the defect.[14,15] Bone grafting is recommended around implants placed in sites where bone volume or density is deficient or where there is a history of implant failure. To achieve optimal results, an osseointegration period of 3-6 months prior to loading is recommended for implants placed in native bone or grafted bone, depending on bone density and healing of the grafted site. While no definitive conclusions have been reached concerning the superiority of native or grafted bone concerning the placement of dental implants, when rehabilitating reconstructed jaws, the clinician may even find it preferable to place implants in grafted bone rather than in normal bone, depending on patient general health and lifestyle (for example, smoking habits). While an early (1996) review of head and neck cancer patients suggested that grafted bone integrates with implants to a higher degree than natural host bone,[16] as was also suggested by a 2009 study involving osseous onlay grafts and native bone,[17] another similar but much more recent (2011) study of irradiated head and neck cancer patients concluded there was no significant difference in implant survival rates between native and grafted bone,18 as did a 2016 study of over 1,200 patients not suffering from cancer.[19] However, another 2016 study concluded that nongrafted sites were by far the optimal environment for implant integration.[20]

Bone grafts fall into four basic categories: Autogenous (or autografts, which will be the main focus of this section), Allogenic (or allografts), Xenogenic, and Synthetic. Autografts are harvested from patients themselves (for example, from the jaw, chin, hip, or leg) and are considered the gold standard for bone grafting not only because the graft is fresh, living tissue (which facilitates bone growth via osteogenesis) but also because rejection/contamination by the recipient bone is not a factor. However, drawbacks to autografts are the need for a second surgical site as well as limited bone supply.

Allografts (harvested from human cadaver bone and freeze-dried to remove water) and xenografts (bone gathered from animals, usually a cow, and treated to facilitate safe, effective use in humans), can serve as platforms onto which adjacent recipient bone

can grow for repair via osteoconduction since allografts alone have no osteoinductive properties to stimulate new bone growth. Synthetic grafts (bone graft substitutes) include allografts treated with extracts (including growth factors, proteins, and collagen) from allograft bone. These grafts include demineralized bone matrix/demineralized freeze-dried bone allografts, combinations of bone graft constituents and growth factors (for example, graft composites such as collagen and ceramics and autograft), and bone morphogenetic proteins (human proteins which facilitate and regulate new bone growth). These synthetic grafts are engineered to enhance the advantages and to minimize the disadvantages of the separate categories of traditional grafting materials.

Thus, the ideal graft material (such as autografts, usually) should transfer an optimal quantity of viable osteocompetent cells—including osteoblasts and cancellous marrow stem cells—to the host site. For the osseointegration of the implant into the grafted site to proceed successfully, the host tissue must have sufficient vascularity to diffuse nutrients to the cells before revascularization occurs and to bud new capillaries into the graft to create a more permanent vascular network. Thus, depending on the amount of new bone that must be formed, donor sites are selected based on their osteocompetent cell density. The graft also consists of islands of mineralized cancellous bone, fibrin from blood clotting, and platelets within the clot (Figure 1-8). In descending order of available cancellous bone, autogenous donor sites include the posterior and anterior ilium, tibial plateau, femoral head, mandibular symphysis, calvaria, rib, and fibula.

Other intraoral sites may also be good choices for autogenous bone harvesting, and non-autogenous materials may be used in some cases. Placement of a graft that consists of endosteal osteoblasts and marrow stem cells and is surrounded by a vascular and cellular tissue bed creates a recipient site with a biochemistry that is hypoxic (O2 tensions of 3 mm to 10 mm Hg), acidotic (pH of 4.0 to 6.0), and rich in lactate. The osteoblasts and stem cells survive the first 3 to 5 days after transplant to the host site largely because of their surface position and ability to absorb nutrients from the recipient tissues. The osteocytes within the mineralized cancellous bone die as a result of their encasement in mineral, which acts as a nutritional barrier. Because the graft is inherently hypoxic and the surrounding tissue is normoxic (50 to 55 mm Hg), an oxygen gradient greater than the 20 mm Hg (usually 35 mm to 55 mm Hg) is established and, in turn, the macrophages are stimulated to secrete macrophage-derived angiogenesis factor (MDAF) and macrophage-derived growth factor (MDGF).

Within the graft, the platelets trapped in the clot degranulate within hours of graft placement, releasing platelet-derived growth factor (PDGF). There-

fore, the inherent properties of the wound, particularly the oxygen gradient phenomenon and PDGF, initiate early angiogenesis from the surrounding capillaries and mitogenesis of the transferred osteocompetent cells. By day three, buds from existing capillaries outside the graft can be detected. These buds penetrate the graft and proliferate between the graft and the cancellous bone network to form a complete network by days 10 to 14. As these capillaries respond to the oxygen gradient, MDAF messengers effectively reduce the oxygen gradient as they perfuse the graft, thus creating a shut-off mechanism that prevents over-angiogenesis.

Although PDG seems to be the earliest messenger to stimulate early osteoid formation, it is probably replaced by MDGF and other mesenchymal tissue stimulators from the TGF-β family. During the first 3 to 7 days after graft placement, the stem cells and endosteal osteoblasts produce only a small amount of osteoid. Over the next few days, osteoid production accelerates after the vascular network is established, presumably because of the availability of oxygen and nutrients. The new osteoid initially forms on the surface of the mineralized cancellous trabeculae from the endosteal osteoblasts. Shortly thereafter, individual osteoid islands develop between the cancellous bone trabeculae, presumably from the stem cells transferred with the graft material. A third source of osteoid production is circulating stem cells, which are attracted to the wound and are believed to seed into the graft and proliferate.

During the first 3 to 4 weeks, this biochemical and cellular phase of bone regeneration coalesces individual osteoid islands, surface osteoid on the cancellous trabeculae, and host bone to clinically consolidate the graft. This process uses the graft's fibrin network as a framework to build upon via osteoconduction. Normally nonmotile cells, such as osteoblasts, may be somewhat motile via the process of endocytosis along the scaffold-like fibrin. During endocytosis, the cell membrane is transferred from the retreating edge of the cell, through the cytoplasm, to the advancing edge to re-form a cell membrane. During this process, the cell slowly advances and secretes its product along the way—in this case, osteoid onto the fibrin network.[21,22] This cellular regeneration phase is often referred to as phase I bone regeneration. It produces disorganized woven bone, similar to fracture callus, which is structurally sound but not as strong as mature bone. The amount of bone formed during phase I depends on the osteocompetent cell density in the graft material. The bone yield can also be enhanced by the clinician's compacting the graft material using a bone mill, followed by syringe compaction and then by further condensing it into the graft site with bone-packing instruments.

Phase I bone undergoes resorption and remodeling, until it is eventually

replaced by phase II bone, which is less cellular, more mineralized, and more structurally organized. Phase II is initiated by osteoclasts that arrive at the graft site through the newly developed vascular network. BMP is released during resorption of both the newly formed phase I bone and the nonviable cancellous trabecular graft. As with normal bone remodeling, BMP acts as the link or couple between bone resorption and new bone apposition. Stem cells in the graft and from the local tissues and the circulatory system respond by osteoblast differentiation and new bone formation. New bone forms while the jaw and graft are in function, developing in response to the demands placed on it. This bone develops into mature Haversian systems and lamellar bone that can withstand normal shear forces from the jaw and impact compressive forces that are typical of dentures and implant-supported prostheses. Histologically, grafts undergo long-term remodeling that is consistent with normal skeletal turnover. A periosteum and endosteum develop as part of this cycle. Although the graft cortex never grows as thick as a normal jaw cortex, the graft itself retains a dense cancellous trabecular pattern that is beneficial for placing dental implants because its density promotes osseointegration of the implant. It can also be beneficial for placing conventional dentures because the dense trabecular bone can easily adapt to a variety of functional stresses. Radiographically, the graft takes on the morphology and cortical outlines of the mandible or maxilla over several years. Preprosthetic procedures, such as soft tissue grafts, can be performed at four months when a functional periosteum has formed. Dental implants can also be placed at this point when treatment is phased.

Osseointegration of Dental Implants

The healing and remodeling of tissues around an implant involves a complex array of events. In this case, osseointegration refers to direct bone anchorage to the implant body, which can provide a foundation to support a prosthesis and can transmit occlusal forces directly to the bone (Figure 1-9). This concept was developed and the term coined by Per-Ingvar Branemark, a professor at the Institute for Applied Biotechnology at the University of Goteborg in Sweden and the inventor of the well-known Branemark implant system. During animal studies of microcirculation in bone repair during the 1950s, Branemark discovered a strong bond between bone and titanium. Today, we know that a fully anchored prosthesis can provide patients with restored masticatory functions that approximate natural dentition.

Several key factors influence successful implant osseointegration, including the characteristics of the implant material (some appear to chemically bond

to bone better than others) and maintenance of implant sterility prior to placement; implant design, shape, and macro and microsurface topography; prevention of excessive heat generation during bone drilling; and placement within bone that has adequate trabecular density, ridge height and width, and systemic health (particularly good vascularity). When recipient bone or graft is deficient in height, the portion of the implant prosthesis that is above the bone is greater than the length of the implant within it, possibly creating a destructive lever arm associated with bone resorption that will "loosen" the implant over time. A ridge that is too narrow (less than 5 mm to accommodate standard 3.75 mm diameter implants) will leave some of the implant placed outside the bone or will force the clinician to use less desirable small-diameter implants to gain the necessary osseointegrated surface area. Likewise, low-density trabecular bone either will frequently fail to osseointegrate or lose its osseointegration over time.[23,24] Ideally, the marginal and apical parts of the implant should be fully engaged in cortical bone or in cancellous bone that has a high proportion of bony trabeculae support. The ingrowth of fibrous tissue between the bone and implant also decreases the chances for long-term success and the ability to withstand mechanical and microbial threats. In some cases these threats can be reduced by protecting against micromobility and by protective barrier membranes used during healing. It is crucial to achieve initial stability for successful osseointegration since a clinically mobile implant has rarely been observed to osseointegrate.[25] Once stability is lost, the implant can only be removed.

Two crucial components in any discussion of osseointegration and implant survival rates are Bone-to-Implant Contact, or BIC (a microscopic measurement of the amounts of surface contact between implant and bone), and Implant Stability Quotient (ISQ), a 1-100 scale measurement of implant stability, ranging from high (greater than 70), to medium (60-70), to low (less than 60), with a general clinical range between 50 and 80 ISQ, with mostly higher ranges in the mandible. Regarding implant stability, BIC and ISQ measurements often diverge, based on bone type. For example, in dense bone, initial stability could be relatively high (for example, greater than 75 ISQ), but such stability does not necessarily mean there is high BIC. Additionally, even if BIC (via osseointegration) increases over time with such an implant, the ISQ can remain unchanged. By contrast, in low or medium-density bone, initial implant stability could be relatively low (say, between 55 and 60 ISQ), but the BIC could be relatively high. As BIC increases via osseointegration, the ISQ can rise correspondingly.

The healing process around an implant is the same as that which occurs in normal primary bone. Research with

titanium dental implants suggests the following three-stage process: the osteophyllic phase, the osteoconductive phase, and the osteoadaptive phase.16 The osteophyllic phase commences when a rough-surface implant is placed into the cancellous marrow space of the mandible or maxilla. Blood is initially present between the implant and bone, and a clot subsequently forms. Only a small amount of bone is in contact with the implant surface; the rest is exposed to extracellular fluid and blood cells. During the initial implant-host interaction, numerous cytokines are released that have a variety of functions, from regulating adhesion molecule production and altering cellular proliferation to enhancing collagen synthesis and regulating bone metabolism. These events also correspond to the beginning of the generalized inflammatory response to the surgical intrusion (Figure 1-10). By the end of the first week, inflammatory cells are responding to foreign antigens introduced by the surgical procedure.

While the inflammatory phase is still active, vascular ingrowth from the surrounding vital tissues begins by about day three, developing into a more mature vascular network during the first three weeks following implant placement. In addition, cellular differentiation, proliferation, and activation begin. Ossification also begins during the first week, and the initial response observed is the migration of osteoblasts from the endosteal surface of the trabecular bone and the inner surface of the buccal and lingual cortex to the implant surface. This migration is likely a response to the release of BMP during implant placement and the initial resorption of bone crushed against the metal surface. The osteophyllic phase lasts about one month.

The osteoconductive phase is initiated once the bone cells reach the implant and spread along the metal surface via osteoconduction, laying down osteoid. Initially, this is an immature connective tissue matrix, and the bone deposited is a thin layer of woven bone called a foot plate (basis stapedis). The fibrocartilaginous callus is eventually remodeled into bone callus (woven and, later, lamellar) in a process similar to endochondral ossification. This process occurs during the next three months (peaking between the third and fourth week) as more bone is added to the total surface area of the implant. Four months after implant placement, the maximum surface area is covered by bone. By this point, a relatively steady state has been reached and no further bone is deposited on the implant surface. The final, or osteoadaptive, phase begins approximately four months after implant placement. A balanced remodeling sequence has begun and continues even after the implants are exposed and loaded. Once loaded, the implants generally do not gain or lose bone contact, but the foot plates thicken in response to the load transmitted through the implant to the surrounding bone, and some reorientation of the vascular pattern may be

detected.

Autologous Blood Concentrates, Bone Grafts, and Dental Implants

One strategy for trying to harness the benefits of growth and differentiation factors is to apply Autologous Blood Concentrates (ABCs) to bone graft sites, including grafts used to rehabilitate the alveolar ridge in preparation for dental implants. For example, the use of platelet-rich plasma in augmenting the severely atrophic posterior maxilla has long been known to have obvious clinical benefits for reducing the healing period for bone maturation, improving graft handling, and accelerating soft tissue healing.[26] Researchers and clinicians have also focused on the possibility of applying polypeptide growth and differentiation factors to enhance bone regeneration more generally. Platelets are a rich source of PDGF, Transforming growth factor beta-1 (TGF-B1), and Transforming growth factor beta-2 (TGF-B2). Studies have shown that the cancellous marrow cells present in graft material harbor receptors for these growth factors.[27] It also has been shown radiographically that adding ABCs to graft material can significantly reduce the time to graft consolidation and maturation, as well as improving the density of trabecular bone.[28] Applying ABCs to graft material amplifies the influence of PDGF and TGF-B, at least during the initial stages of bone regeneration. The platelets degranulate within 3 to 5 days, and their initial growth factor activity may expire within 7 to 10 days. The initial boost that ABCs appears to give to the process of bone regeneration can be useful because ABCs "jump-start" the cascade of regenerative events that continue to form a mature graft.

Current research and clinical experience also suggest that adding certain growth factors to bone graft material may also increase the amount of phase I bone that forms. In laboratory studies and some early human trials involving graft enhancement, BMPs (particularly recombinant DNA-produced BMP), TGF-β, PDGF, and IGF have shown promise in their ability to increase the speed and quantity of bone regeneration.[29] Clinical studies on adding platelet-rich plasma (PRP) to graft material have demonstrated its ability to induce early consolidation and graft mineralization in half the time with a 15% to 30% improvement in trabecular bone density.10,30-32 It has been theorized that the enhanced presence of PDGF initiates osteocompetent cell activity more completely than that which inherently occurs in the graft and clot setting alone. The enhanced fibrin network created by PRP may also enhance osteoconduction throughout the graft, supporting consolidation.

Because of factors involving its availability and cost, platelet-rich plasma

(PRP) has become an increasingly popular clinical tool as an alternative source of growth factors for several types of surgery, including oral bone regenerative procedures. PRP is a concentrated autologous source of several growth factors, particularly platelet-derived growth factor (PDGF) and transforming growth factor- (TGF- 1 and TGF- 2), as well as vascular endothelial growth factor, insulin-like growth factor, and other growth factors possibly contained within platelets. Once the clinician prepares PRP by extracting a small amount of a patient's own blood and then sequestering and concentrating the platelets, which is a process that requires 20-30 minutes in an outpatient clinical setting, PRP can be used to enhance graft material to form a growth-factor rich membrane or to enhance a traditional membrane barrier.

Its fibrinogen component also makes PRP an excellent hemostatic tool, tissue sealant, wound stabilizer, and graft condenser through the creation of a gel-like substance that allows for sculpting and excellent adherence in defects. Researchers have shown radiographically that adding PRP to graft material significantly accelerates the rate of bone formation and improves trabecular bone density as compared to sites treated with only autogenous graft material.[33,34] Widespread clinical reports and recent published research also suggest that PRP significantly enhances soft tissue healing; reduces bleeding, edema, and scarring; and decreases a patient's self-reported pain levels postoperatively.[35-38] Some evidence even suggests that adding PRP to graft material leads to bone growth that is more dense than native bone, a potential benefit that has not been reported in studies in which bone morphogenetic proteins or growth factors are applied singly.[39] PRP growth factors are particularly attractive for cases in which conditions typically reduce the success of bone grafts and osseointegration.[40]

Thus, growth factors perform a wide range of functions. Platelet-derived growth factor (PDGF) is considered one of the principal healing hormones present in any wound. It initiates healing of connective tissue, including bone regeneration and repair. PDGF is a potent mitogen, angiogen, and upregulator of other growth factors. Mitogens trigger an increased number of healing cells, while angiogens generate new capillaries. Upregulation of other growth factors promotes fibroblastic and osteoblastic functions, cellular differentiation, and accelerated effects on other cells, such as macrophages. There is also evidence that PDFG increases the rate of stem cell proliferation.[41]
TGF-B1 and TGF-B2 are involved with general tissue repair and bone regeneration. Their most important role appears to be chemotaxis and mitogenesis of osteoblast precursors and the ability to stimulate deposition of collagen matrix for wound healing

and bone. These growth factors also enhance bone formation by increasing the rate of stem cell proliferation, and they inhibit some degree of osteoclast formation and thus bone resorption.
The fibrin component of PRP helps to bind the graft material and assists in osteoconduction throughout the graft by acting as a scaffold to support the growth of new bone. In addition, PRP modulates and upregulates the function of one growth factor in the presence of the other growth factors. This feature differentiates PRP growth factors from other growth factors, which are single growth factors that only function within a single regeneration pathway.

Research that focuses specifically on the usefulness of ABCs for bone grafts related to implants remains cutting edge. The results of the first clinical study in humans appear promising and are in agreement with preclinical studies in animals. Results showed enhanced bone regeneration when PDFG, TGF-B, or other growth factors were applied.[42] Several orthopedic studies also have shown evidence of the benefits of autologous fibrin that was obtained containing PDGF and TGF-B.[43]

In a controlled trial of patients undergoing bone augmentation for resected mandibles, investigators radiographically assessed the sites that were treated with graft material plus PRP and the control sites that were treated with graft material only. At two, four, and six months, the grafts containing the PRP were consistently rated as having reached maturity levels nearly twice their actual levels. Histomorphometric assessment also revealed bone graft densities in the PRP-treated group that were 15% to 30% higher than the control group at six months.[44]
A 2015 study attempted to determine whether bone quality was enhanced before implant placement in extraction sockets treated with mineralized freeze-dried bone allograft (FDBA) alone or when combined with growth factors. One of the four randomized groups in the study received FDBA/β-TCP/platelet-rich plasma (PRP)/collagen plug, and another group received FDBA/β-TCP/recombinant human platelet-derived growth factor BB (rh-PDGF-BB)/collagen plug. The study concluded that when implants were placed, bone grafting had enhanced bone quality, that PRP and rhPDGF-BB enhanced bone quality (removing D4 bone quality in the sockets), and that using PRP or rhPDGF-BB could facilitate the healing of extraction sockets while also decreasing the healing time.[45]

Summary

A general overview of the essential characteristics of human bone can provide dental clinicians with the contextual understanding that they need for grasping the more specialized application of this understanding to dental

implantology practices. In addition to providing such a synopsis, this current study also attempts to show how bone biology and physiology are crucial elements of specific clinical practices associated generally with dental and maxillofacial protocols and particularly with dental implantology. The first part of this study—covering bone cells and metabolism, bone's macro/microscopic and molecular structure, and bone modeling/remodeling—hopefully sets the stage for a more in depth discussion of the applications to dental implantology covered in part two of the study, which discusses bone formation/modeling with bone grafts, osseointegration of dental implants, and autologous blood concentrates, including many resources for follow-up. Of special importance to the dental implantologist should be subjects in part two of the study which discuss the differences between native or grafted bone concerning the placement of dental implants, how osseointegration and implant survival rates are related to Bone-to-Implant Contact (BIC) and Implant Stability Quotient (ISQ), and how platelet-rich plasma (PRP) has become an increasingly popular clinical tool as an alternative source of growth factors for several types of surgery, including oral bone regenerative procedures and dental implants.

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CHAPTER

2 Introduction to Augmentation Grafting of the Maxillary Sinus

Placing implants in the edentulous posterior maxilla poses several problems, including inadequate ridge width and close approximation of the maxillary sinus floor to the alveolar crestal bone (pneumatization of the maxillary sinus).[1,2] Pneumatization of the sinus typically occurs with aging, minimizing or eliminating vertical bone for placing endosteal implants. Studies have tried to determine the most effective methods for implant placement in insufficient bone in the mandible and maxilla[3] because as little as 1 mm bone can separate the alveolar mucosa and the maxillary sinus (Fig.1-1).[4-6]

For nearly 20 years, increasing the vertical height and improving bone quality in the sinus floor have become increasingly successful for patients with a severely atrophic posterior maxilla;[7-9] grafting preferences include autogenous bone or bone substitutes.[10] Implants placed in bone-grafted areas can have an even higher bone-to-implant contact and greater pull-out resistance than normal bone[11] or at least comparable results with native bone only,[12] demonstrating that bone grafting is generally recommended for placing implants where bone volume or density is deficient, particularly in sites such as the maxilla that have a history of implant failure.

Grafting of the antral floor for implant placement was developed in the early 1970s, and the method is still widely used today (Fig. 1-2).[13-16] The alveolar crestal access to the maxillary sinus led to a modified Caldwell-Luc procedure developed to approach the sinus by infracturing the lateral wall of the

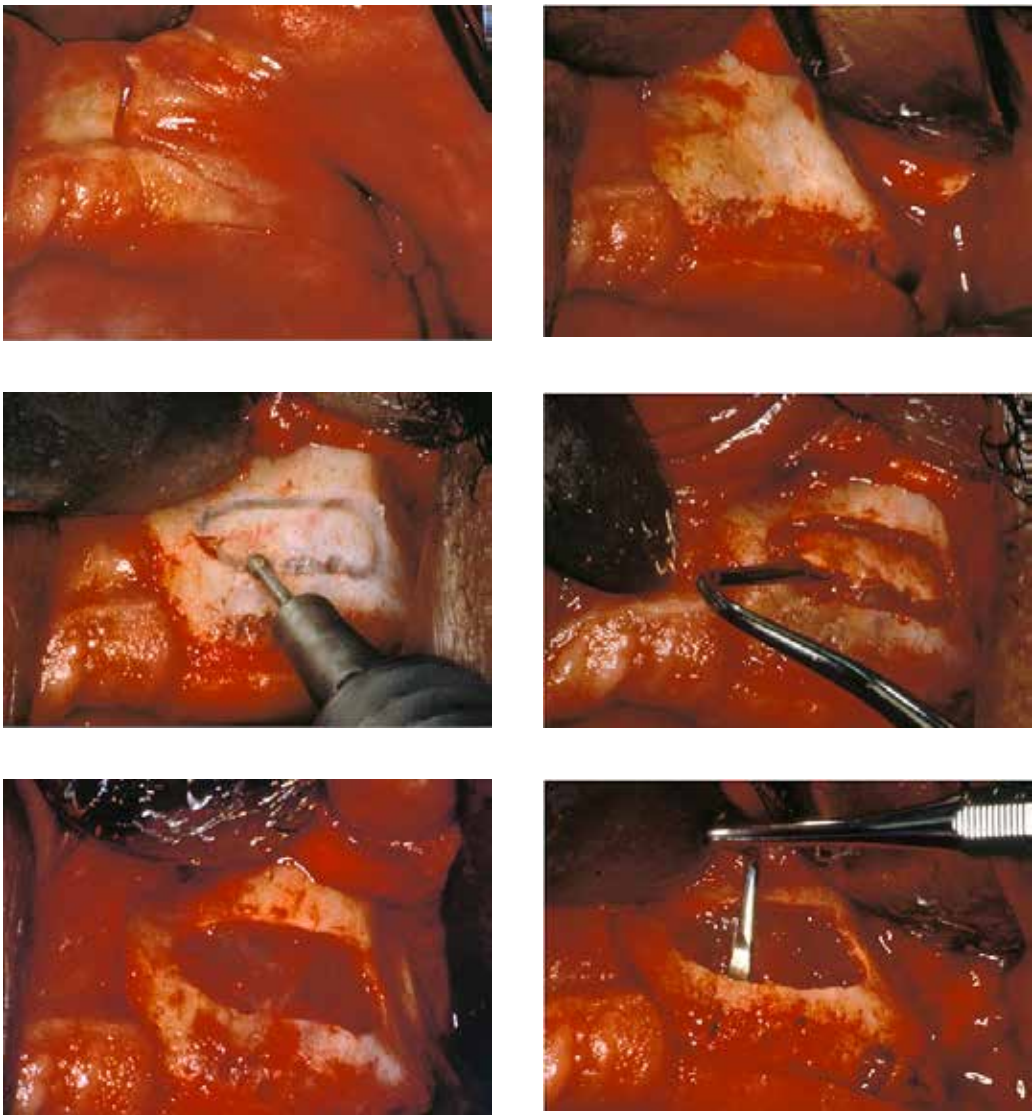


Fig. 2-1

Sinus pneumatization often minimizes or eliminates the vertical bone available for implant placement in the auxillary sinus, necessitation bone grafting of the sinus floor to increase vertical height and improve bone quality

Placing implants in the edentulous posterior maxilla poses several problems, including inadequate ridge width and close approximation of the maxillary sinus floor to the alveolar crestal bone (pneumatization of the maxillary sinus).[1,2] Pneumatization of the sinus typically occurs with aging, minimizing or eliminating vertical bone for placing endosteal implants. Studies have tried to determine the most effective methods for implant placement in insufficient bone in the mandible and maxilla[3] because as little as 1 mm bone can separate the alveolar mucosa and the maxillary sinus (Fig. 2-1).[4-6]

For nearly 20 years, increasing the vertical height and improving bone quality in the sinus floor have become increasingly successful for patients with a severely atrophic posterior maxilla;[7-9] grafting preferences include autogenous bone or bone substitutes.[10] Implants placed in bone-grafted areas can have an even higher bone-to-implant

Fig. 1-2

a The classic window design for augmentation grafting of the maxillary sinus. A rectangular or trapezoidal osteotomy is created and the superior portion is not contiguous. The underlying Schneiderian membrane is left intact. A modified and recommended technique is presented later in this chapter.

b The bony island is fractured with an osteotome and mallet and elevated superiorly while simultaneously elevating the underlying Schneiderian membrane.

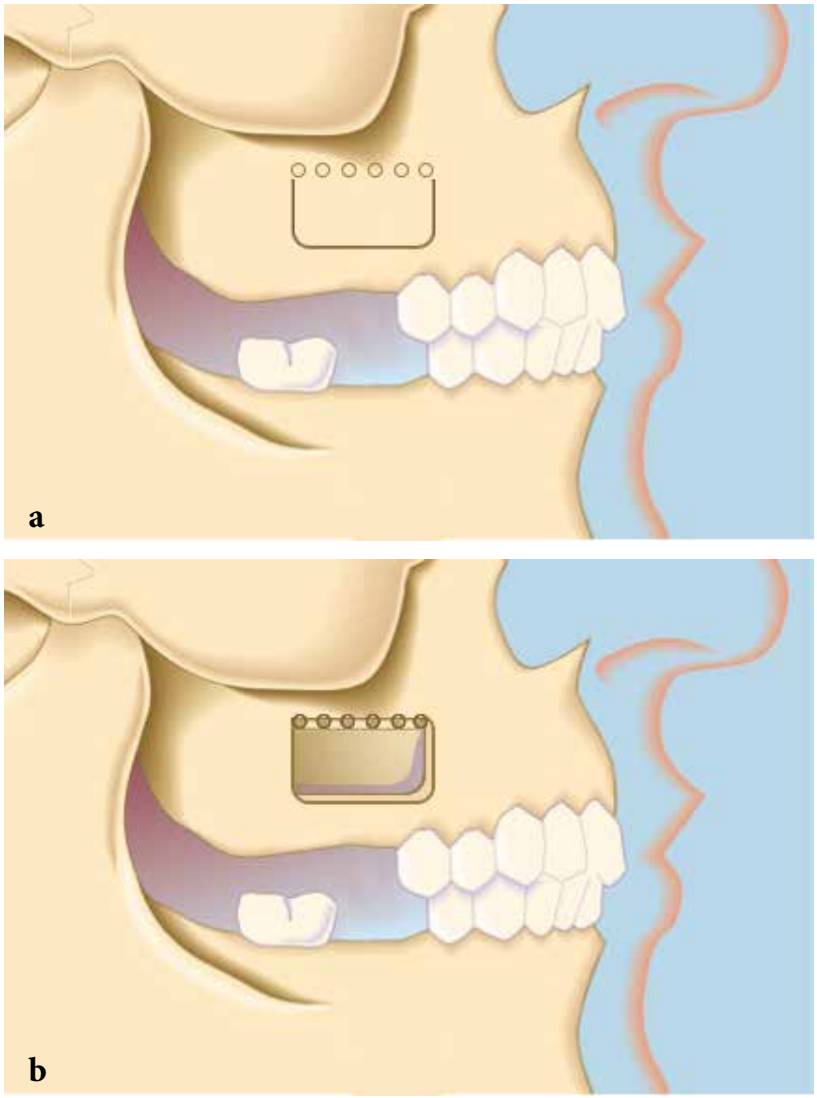
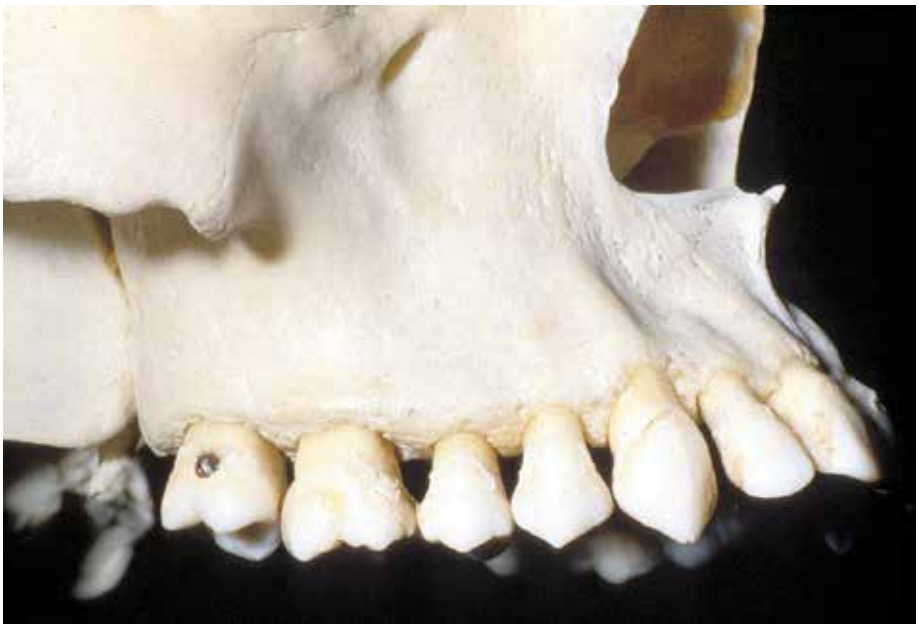


Fig. 1-3

Lateral wall of the maxilla. Note the relationship of the infraorbital foramen and the sinus area. Also note the position of the zygoma in relation to the area for the osteotomy; this will be a landmark to use when designing the osteotomy. It is important to maintain the window inferior to the zygoma to minimize the chances of damaging the infraorbital nerve with the bur or the retractor.



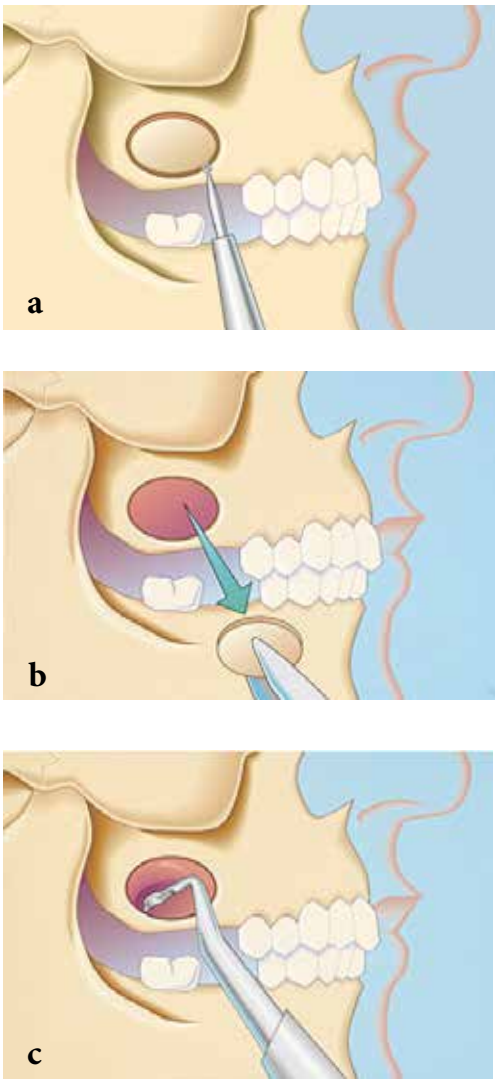


Fig. 2-4

Sinus augmentation grafting technique using rough-surface implants and a modified window shape and design.

a The ideal shape of the osteotomy should be ovoid and contiguous. In this manner, the chances of Schneiderian membrane perforation with sharp corners from a rectangular or trapezoidal osteotomy are minimized. This also minimizes membrane perforations due to sharp edges arising from a greenstick-fractured area superiorly.

b Removal of the island of bone. This should be performed gently to minimize the chances of perforating the underlying membrane.

c Sinus membrane elevation using a specially designed curette. Sharp curettes should be used and the membrane should be reflected off the bone as opposed to attempting to simply push it off the bone.

contact and greater pull-out resistance than normal bone[11] or at least comparable results with native bone only,[12] demonstrating that bone grafting is generally recommended for placing implants where bone volume or density is deficient, particularly in sites such as the maxilla that have a history of implant failure.

Grafting of the antral floor for implant placement was developed in the early 1970s, and the method is still widely used today (Fig. 2-2).[13-16] The alveolar crestal access to the maxillary sinus led to a modified Caldwell-Luc procedure developed to approach the sinus by infracturing the lateral wall of the maxilla and using the wall to elevate the maxillary sinus membrane (Fig. 2-3). The clinician can place an autogenous bone graft in the area once occupied by the inferior third of the sinus. Templates can be used to place implants precisely during such a procedure,[17] and non-drilling techniques for placing implants have also been used.[18] Boyne and James (1980) de-

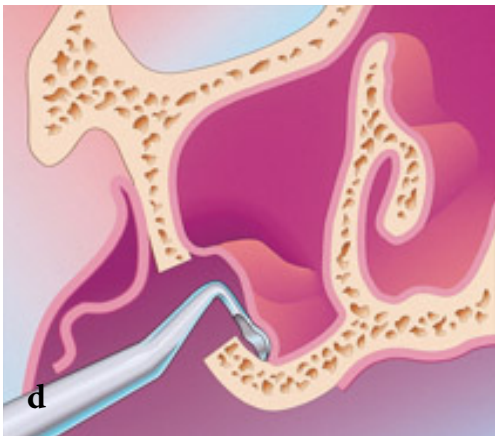
Fig. 2-4 (cont'd)

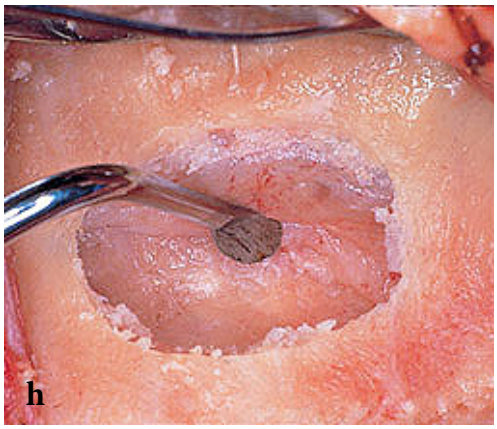
d Coronal view of sinus membrane elevation. Note that the inferior portion of the window is approximately 3 mm above the sinus floor. This allows the surgeon to avoid some 1 to 2 mm sinus septa during elevation of the sinus window and allows for a small lip of bone to help contain the graft material. The superior portion of the window depends on the size of the implant that will be placed. The superior portion of the window should be measured from the ridge crest and should be at least the same height as the implant that is planned for the area.

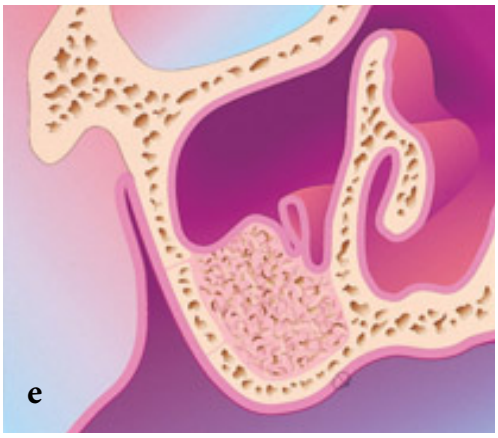
e Sinus cavity grafted with the amount of material needed for future implant placement. Note that this does not obliterate the entire sinus cavity.

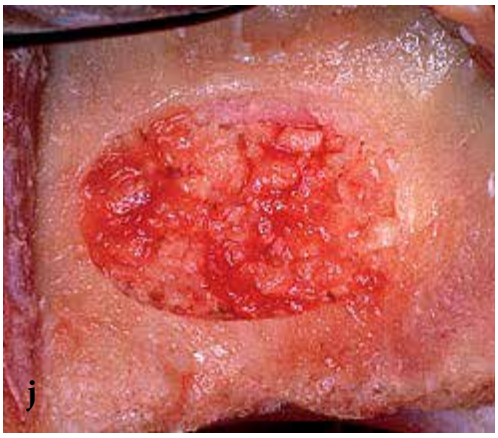
f Coronal view of the grafted sinus cavity after some maturation of the graft has occurred.

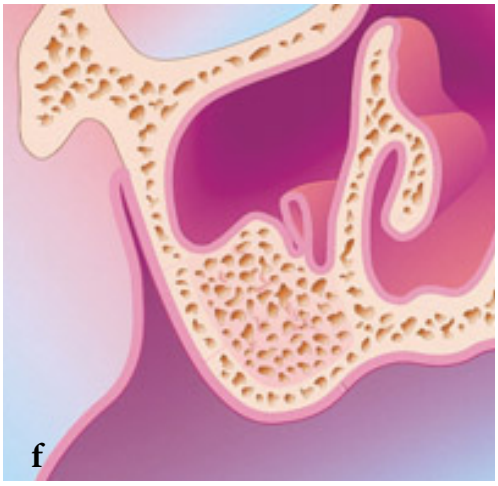
g Coronal view of the implant site after the implant is placed and surrounded by sufficient bone.

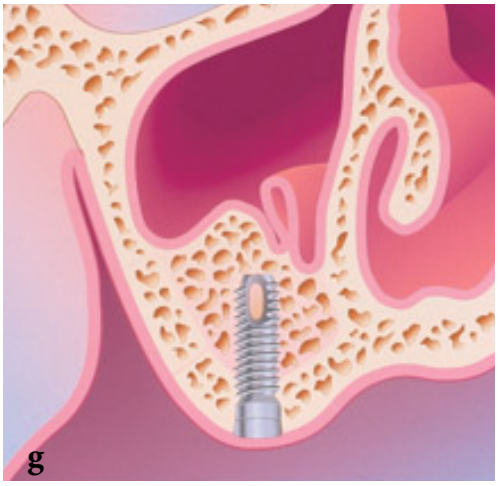










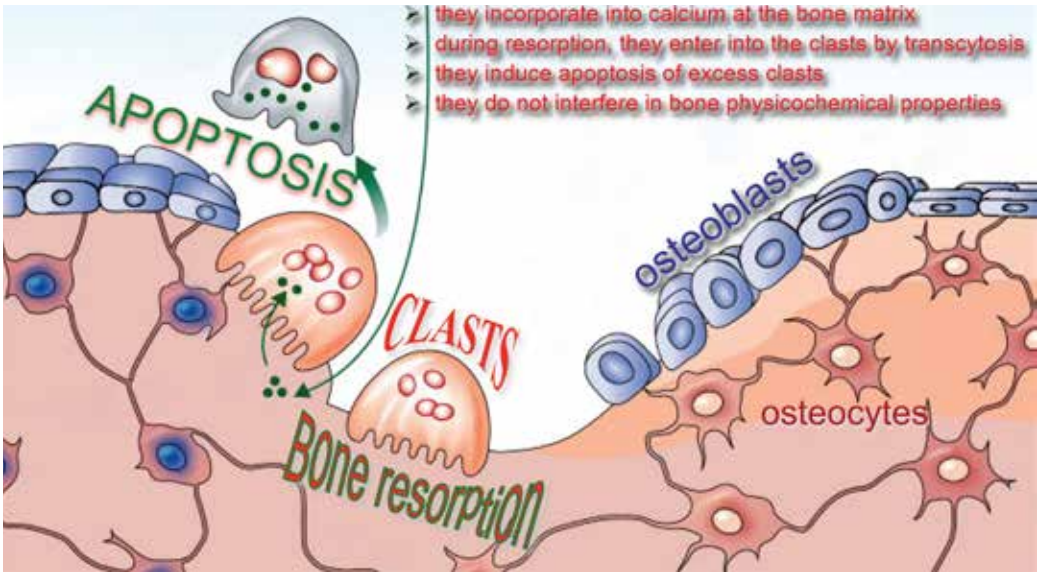


Medical History
Seasonal Allergies, Allergic Rhinitis or Sinus Stuffiness
Tobacco Use and Ability to Refrain Before and After Surgery
Impact of Nicotine on Bone Healing • Peripheral Vasoconstriction • Tissue Ischemia • Decreased Osteoblast Activity • Decreased Oxygen Tension
Bisphosphonates

scribed a similar clinical procedure and demonstrated bone formation in the maxillary antrum following placement of autogenous marrow and cancellous bone in the maxillary sinus.[19] Their techniques, with variations, have been followed successfully for decades.[2,5,20] In 1984, Misch modified the technique, simultaneously combining sinus augmentation and blade-vent implant placement.[21] Innovations followed.[22,23] A further development by Garg and Quinones (1997) combined sinus augmentation and rough-surface implants, modifying the window shape and design along with recommended instrumentation[24] (Fig. 2-4). A number of modifications followed, with different surgical approaches, type and donor site of grafts, and implants.[25-29] Notably, sinus lift grafting and implant placement can be accomplished as either a one-step or two-step procedure.[1,30-44] Since 2000, a number of techniques, types of implants and grafting materials, and accompanying armamentarium have been used to accommodate the special needs of implant placement in the maxillary sinus under a variety of patient conditions.[2,5,6,12,28,45-60] Bone grafts and implant placement can be performed at the same time with sufficient alveolar bone width and only partial pneumatization of the sinus. Advantages to the one-step procedure include minimizing total treatment time by eliminating a second surgical procedure and of allowing a coordinated consolidation of the graft around the implant.[1] Formerly, many clinicians thought that host bone measuring less than 5 mm high was inadequate to place endosteal implants, so they favored the two-step ap-

Fig. 2-5

Osteoclastic activity of bone resorption.



proach, in which implant placement is delayed until 4 to 6 months after graft placement.[31,32] However, success has been reported using the one-step approach for posterior maxillary ridges measuring as little as 1 mm high,[4,61-67] the critical factor appearing to be adequate ridge width, not height.

Since few vital anatomic structures encroach upon the surgical site, the risks with sinus lift grafting are negligible, morbidity is low, and postoperative complications can be treated relatively easily with medical or surgical intervention. Bone response is excellent, and different graft materials produce bone that is demonstrable on histologic examination.[61] The graft and new bone appear to remodel in response to functional loading. The prosthetic alternatives are also predictable; fixed, fixed removable, or removable prosthetic reconstructions can be placed over implants within the sinus graft.[1]

CHAPTER

3 Maxilary Sinus Anatomy & Physiology

Maxillary bone is primarily medullary (i.e., spongy) (Fig. 3-1) and finely trabecular. The quantity and osseous density of bone in the maxilla is lower than premaxillary bone or mandibular bone. Adjacent cortices consist of compact bone, though generally very thin, providing minimal strength compared with the cortices surrounding the mandible. Because of its spongy nature, medullary bone must establish a stress-bearing surface next to an endosteal implant for the functioning implant to remain stable and to transmit physiologic load to the supporting bone.[13,68-70]

The maxillary sinus is an approximately 15-mL-volume air space, but the actual size depends on bone resorption. The sinus resembles a sloped paperweight, with its largest and only flat side composing the medial wall (which is also the lateral wall of the nasal cavity).[71-76] Septa may divide the sinus into two or more communicating cavities. The sinus begins to form in the second to third year of life, completing formation by age eight. It has a nonphysiologic drainage port high on the medial wall (maxillary ostium) that drains into the middle meatus of the nose (Fig. 3-2). The ostium is considered nonphysiologic because it serves as an overflow drain rather than as a dependent complete drainage system. The bony walls of the sinus are thin except for the anterior wall and the alveolar ridge in dentate individuals. In the edentulous, the alveolar bone is frequently atrophied and may be only 1 mm to 2 mm thick, making it unsuitable as an implant site without sinus-lift augmentation.

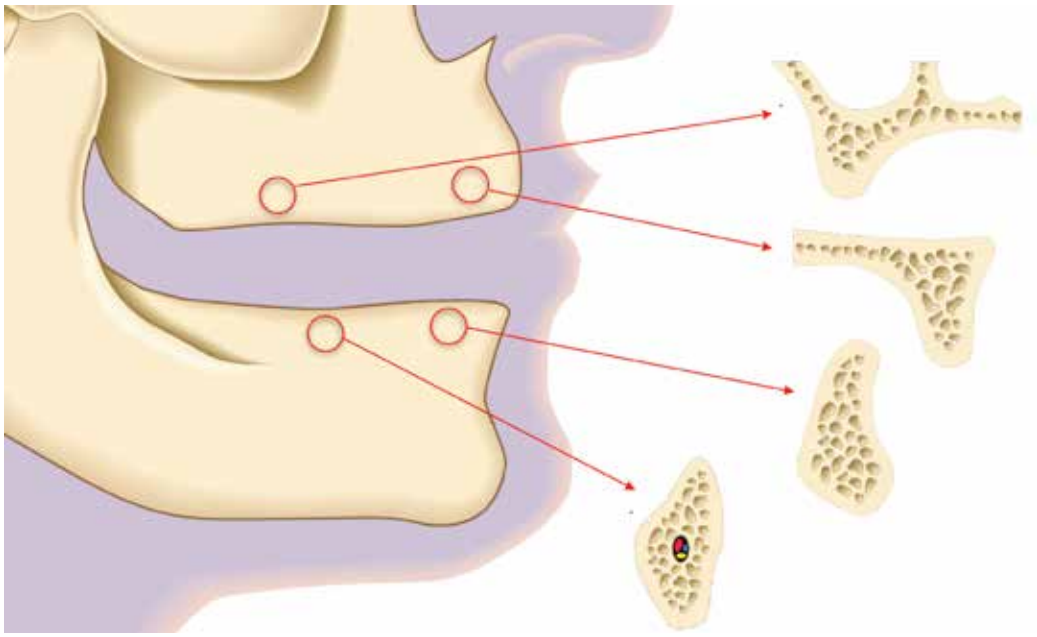
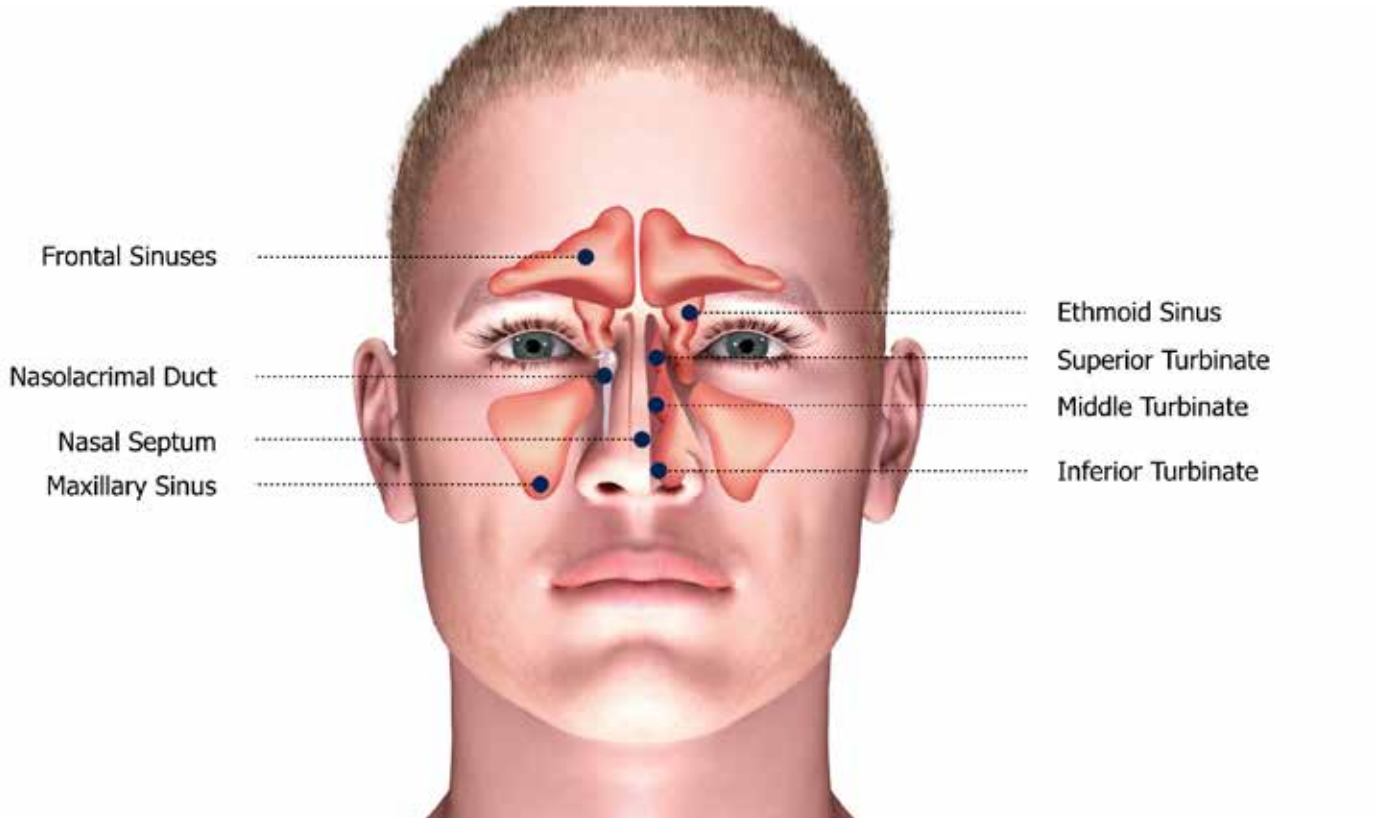


Fig. 3-1

Different success rates of implants in different regions of the oral cavity have been shown in the literature.

The maxillary sinus is lined with a pseudostratified columnar epithelium, also called the Schneiderian membrane. Beneath the surface epithelium is a loosely cellular but highly vascular thin tissue. Beneath this is a periosteum. The delicate mucosa of the sinus attaches to the periosteum on its osseous surface. However, this feature is not an important source of bone formation in sinus lift surgery. A thin layer of respiratory epithelium, which lines the Schneiderian membrane, cannot be differentiated from the periosteum of the bones to which it is firmly affixed.

The blood supply to the maxilla normally is from three arteries—the superior labial, anterior ethmoidal, and, primarily, the internal maxillary. The area of sinus lift surgery is mainly supplied by branches from the internal maxillary artery. The sinus floor gets some of its blood from the greater and lesser palatine vessels as well as from the incisal artery, a terminal branch of the sphenopalatine artery (yet another portion of the internal maxillary artery). These vessels penetrate the bony palate and ramify within the sinus floor and its medial and lateral walls. Another vascular contributor is the posterosuperior alveolar artery, which enters the maxilla in the superior tuberosity area to supply most of the posterior and lateral walls. The infraorbital branch of the internal maxillary artery helps to supply blood to the superolateral sinus area. The anterior ethmoidal artery, a terminal branch of the internal carotid system (via the ophthalmic artery), supplies the superomedial sinus area (Fig. 3-6).



Topography of Sinus Membrane
Sinus Membrane - aka Schneiderian membrane
Contains columnar ciliated epithelium, with mucus goblets
Has fewer (in comparison to other sinuses) blood vessels accounting for paler color
Has fewer osteoblasts (which may account for continued enlargement after tooth loss)
Has fewer elastic fibers, (making elevation easier). Thickness varies between 0.3 - 0.8mm
The cilia beat towards the ostium (propelling debris trapped in the mucous layer)

Maxillary Sinus Physiology

The maxillary sinus warms breathed air and provides resonance to the voice. The sinus also assists the scalp veins and intracranial venous sinuses in dissipating the intense heat produced by the metabolically active human brain. The sinus also lightens the craniofacial complex. The maxillary sinus is self-maintained by postural drainage and actions of the ciliated epithelial lining (Fig. 2-3), which propels bacteria toward the ostium. The sinus also produces mucus-containing lysosomes and immunoglobulins. The rich vascularity of the sinus membrane also helps to maintain its healthy state by allowing lymphocytic and immunoglobulin access to the membrane and sinus cavity. The healthy sinus contains its own flora, of which Haemophilus species are the most common. Other common flora may include streptococci, anaerobic gram-positive cocci, and aerobic gram-negative rods.

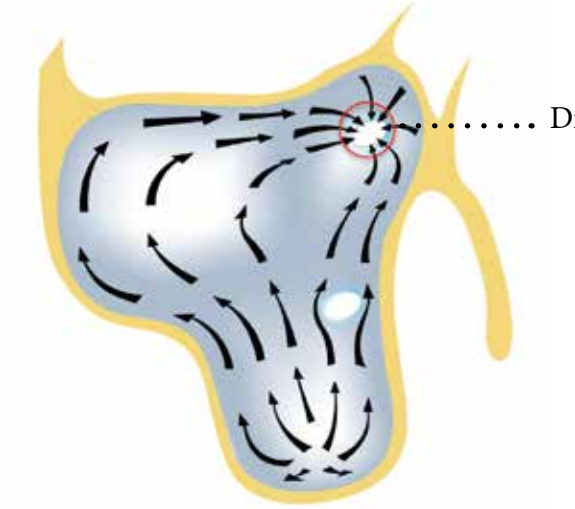


Fig. 3-2

Drainage port located high on the medial wall (maxillary ostium) that drains into the middle meatus of the nose.

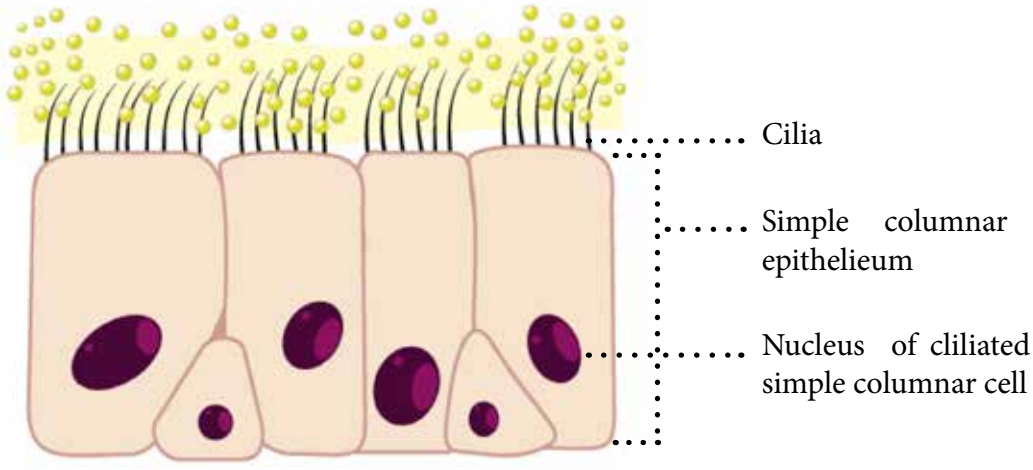


Fig. 3-3

Structure of a Ciliated Epithelial lining in the sinus.

Fig. 3-4

Coronal aspect of a decalcified histologic section of a maxillary ridge and its relationship to the sinus cavity. Note the spongy nature of the bone in this area.

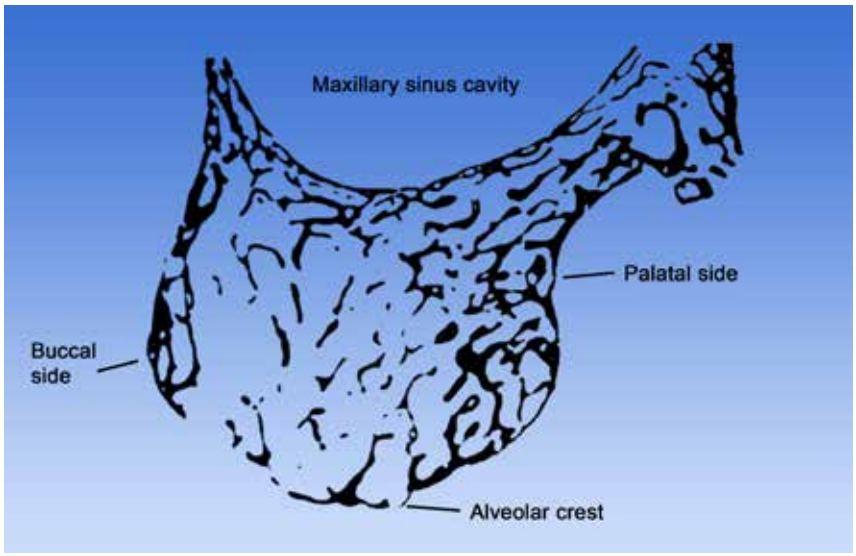
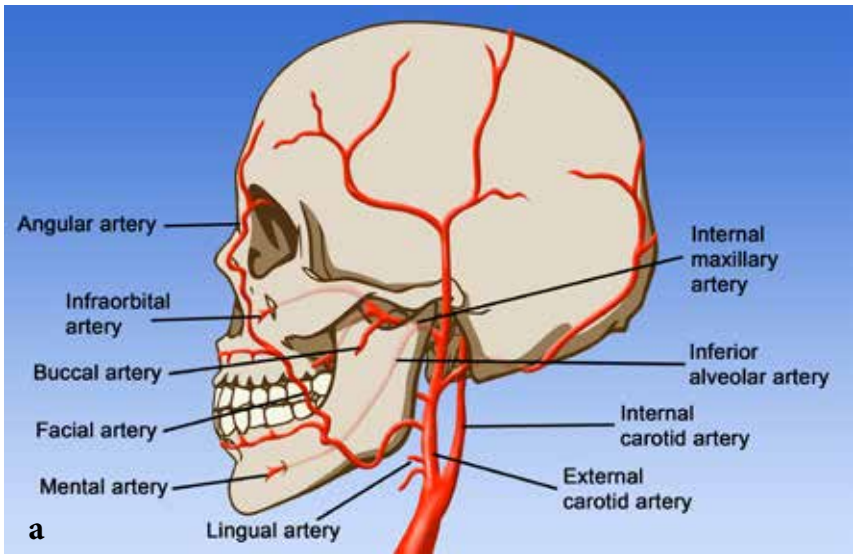
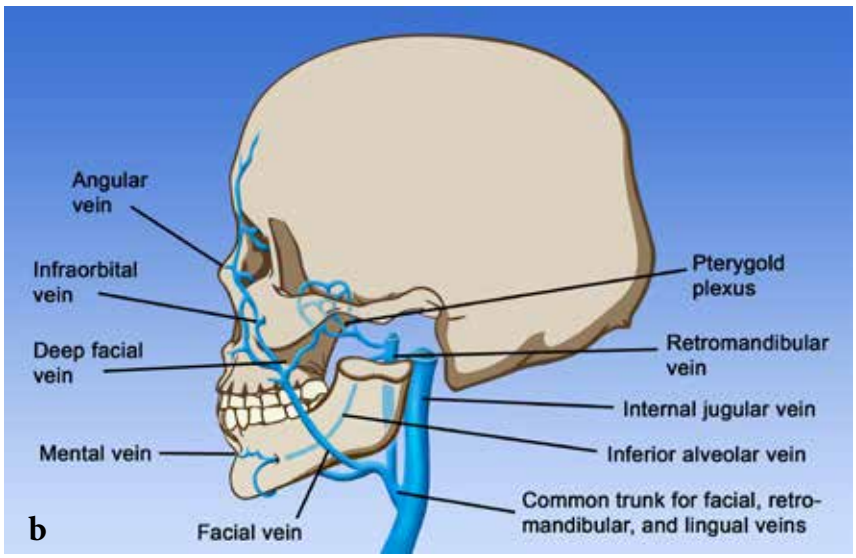


Fig. 3-5

a Blood supply to the sinus starting at the common carotid artery.

b Venous drainage from the facial area.





CHAPTER

4 Mechanisms of Bone Grafting and Grafting Materials

A dynamic process, bone grafting (transplanted osteogenesis), is accomplished by cellular regeneration, which produces osteoid that becomes mineralized. A graft is not a solid bone block that heals into place.[77-79] Bone grafting is accomplished through osteogenesis, osteoinduction, and/or osteoconduction.[80-86] Osteogenesis refers to the formation and development of bone by osteocompetent cells. Osteogenic graft material, derived from or composed of tissue involved in the natural growth and repair of bone, can encourage bone formation in soft tissues and can stimulate faster bone growth in bone implant sites.

Osteoinduction is the process of activating osteogenesis through the recruitment of cells from the surrounding natural bone, which then differentiate into bone-forming cells. Osteoinductive grafts can enhance bone regeneration, sometimes even resulting in the extension or growth of bone where it is not normally found. Osteoconduction is the process by which the graft material acts as a nonviable scaffold onto which and within which the patient's own natural bone grows. Osteoconductive grafts are conducive to bone growth and allow apposition from existing bone but do not produce or trigger bone formation themselves.

Max²lary Sinus Grafting 3 Goals
Create bone in the posterior maxilla
Achieve osseointegration in that bone
Maintain occlusal function under load in that bone

Bone-Grafting Materials

Many materials have been used for sinus lift procedures, including autogenous bone,[30-35] bone allografts,[36,80,83,85,87-93] and alloplasts (such as tricalcium phosphate , or TCP), resorbable and nonresorbable hydroxyapatite,[1,83,86,94-98] bovine-derived bone mineral,[99-101] and bioactive glasses. An ideal graft is nontoxic, nonantigenic, noncarcinogenic, strong, resilient, easily fabricated, able to permit tissue attachment, resistant to infection, readily available, and inexpensive.[28,102,103]

Autogenous Bone

There is no official consensus as to which graft material or combination of materials is best for augmenting the sinus antral void created by the sinus lift operation.[1,104-108] Autogenous bone has long been considered the gold standard among grafting materials because of its highly osteogenic, osteoinductive, and osteoconductive properties, a combination not found in the alternatives.[6,109] These properties allow bone to form more rapidly and in conditions where significant bone augmentation or repair is required. A 1993 histomorphometric study of patients who underwent maxillary sinus augmentation described the bone composition of four different graft materials using biopsies taken from graft sites at the time of implant placement.[104] Particulated autogenous chin grafts contained 59.4% bone; composite grafts of hydroxyapatite and chin bone contained 44.4% bone; grafts of hydroxyapatite alone contained 20.3% bone; and grafts of demineralized freeze-dried bone alone contained 4.6% bone. A similar study revealed that autogenous iliac bone grafts contained 53% bone; and 50-50 composite grafts of autogenous chin bone and hydroxyapatite granules contained 44% bone.[109]

Autogenous Harvest Sites	
Posterior Iliac Crest	Block and/or Particulate, 140 cc's
Anterior Iliac Crest	Block and/or Particulate, 70 cc's
Tibia	Particulate, 20-40 cc's
Cranium	Dense Cortical Block, 40 cc's
Ascending Ramus	Block, 5-10 cc's
Anterior Mandible	Block and Particulate, 5 cc's
Tuberosity	Particulate, 2 cc's
Misc	Bone Scrappers, Suction Traps, etc.

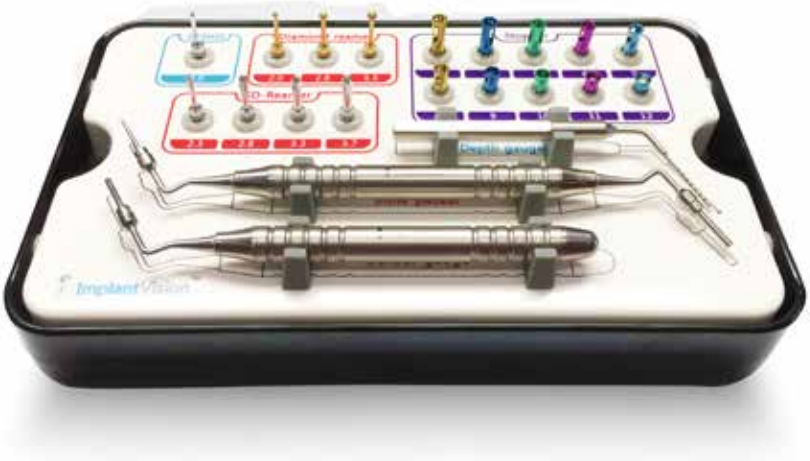


Fig. 4-1

Crestal Approach Kit - enables safe sinus lifting using specially designed reamer.

Fig. 4-2

Lateral Approach Kit - enables to make sinus lateral window in safe and speedy way in case of 1-3mm residual bone, perforated membrane at crestal approach or placement of multiple impants.

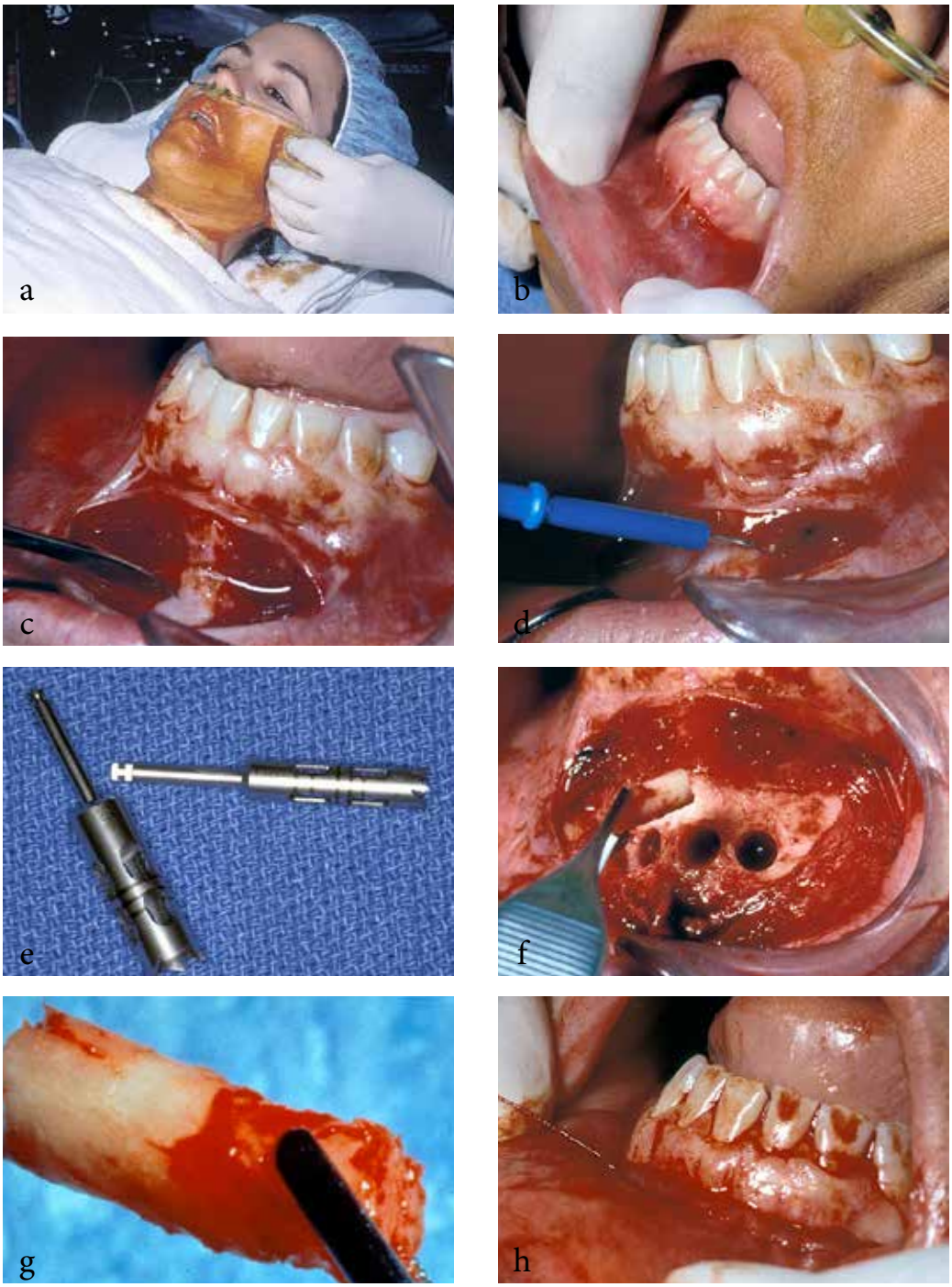


Fig. 4-3

a Preparing the patient for bone harvest surgery

b Visualizing the mucogingival junction

c Making a straight incision through mucosa and muscle down to underlying bone from canine to canine approx. 5 mm below the mucogingival junction

d Utilizing pressure and electrocautery to cauterize any small bleeding veessles

e 4 or 6mm trepine burs are being used to harvest bone from the intra mandilbe.

f In this case, 4 separte cores are harvested

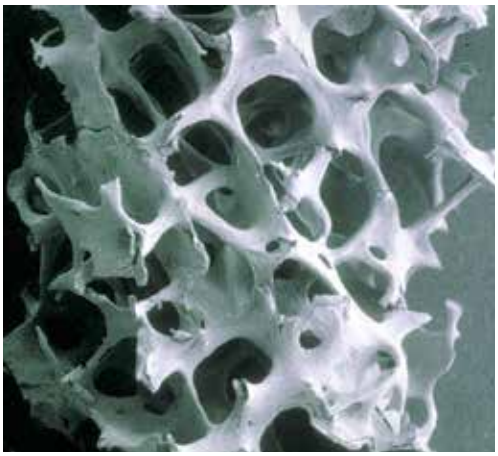
g Close up of one of the cores. It is easy to see on the left the dense cortical bone and on the right the much more vascular and less dense spongy bone.

h After closing the muscle and periostium in the first layer, the mucosa is closed in the second layer.

Cancellous particulated bone from the iliac crest or the tibial plateau is an excellent source of autogenous graft material.[110-111] Intraoral sites such as the mandibular symphysis, maxillary tuberosity, ramus, and exostoses and debris from an implant osteotomy have also been used with success.[32,36,37,83,112-114] Mandibular bone grafts reportedly resorb less than do iliac crest grafts,[32,37] and the procedure can be easily accomplished in an office setting with the patient under parenteral sedation and local anesthesia,

Fig. 4-4

Scanning electron micrograft of freeze dried bone allograft showing its structure and porosities



resulting in lower costs and better patient acceptance.

A disadvantage of intraorally obtained bone grafts is that donor sites provide a smaller volume of bone than that which can be obtained from the iliac crest or tibial plateau. A typical sinus requires approximately 4 mL to 5 mL of bone volume for grafting dental implants. The total graft volume required is naturally dependent on the amount of bone resorption (sinus pneumatization and ridge resorption) . Typically, 5 mL of bone can be harvested from the anterior mandible, 5 mL to 10 mL from the ascending ramus, 20 mL to 40 mL from the tibial head, 70 mL from the anterior ilium, and approximately 140 mL from the posterior iliac crest.

The use of cortical and corticocancellous blocks adapted to the sinus floor has also been reported, though healing time is longer compared with that associated with particulated graft material.[115,116] In a 6-year follow-up investigation of 216 sinus lift procedures with immediate placement of 467 implants into bone measuring 1 mm to 5 mm high, Khoury observed the best bone regeneration in patients grafted completely with autogenous material comprising a percentage of cortical bone.[4]

The choice of donor site usually depends on the volume and type of bone desired. In extremely healthy patients, patients with minimal sinus resorption, and patients who refuse to undergo an extraoral bone graft harvest, expanding the volume of autogenous bone harvested intraorally by combining it with other graft materials, such as allografts or alloplasts, may be appropriate. However, some recent studies indicate that bone formed in autogenous bone-grafted sinuses is retained significantly longer than in sites grafted with a combination of autogenous and demineralized freeze-dried bone allografts (DFDBA).[10,117] Lorenzetti et al showed that maxillary sinuses grafted with a combination of autogenous bone and hydroxyapatite granules were clearly distinguishable and surrounded by only a very thin layer of bone.[118]

Allografts

Bone allografts such as freeze-dried bone allografts (FDBA) or demineralized freeze-dried bone allografts (DFDBA) may be cortical or trabecular. They are obtained from cadavers or living donors other than the patients, processed under complete sterility, and

Alloplasts / Xenografts	
Bioactive Ceramics	Perioglass
	Biogran
	Osteograf-LD
Polymers	HTR Polymer
Hydroxyapatites	Osteograf-N
	PepGen
	Bio-Oss
	BoneOss
	Interpore 200
Miscellaneous	Calcium Sulfate
	Tricalcium Phosphate

stored in bone banks. Fresh allografts are the most antigenic; however, this antigenicity can be reduced considerably by freezing or freeze-drying the bone, as is customary.[87]

Whether these grafts form bone by osteoinduction, osteoconduction, or some combination of both is the subject of continued debate. In the 1960s, Urist suggested that allografts form bone by osteoinduction because they contain osteoinductive proteins called bone morphogenetic proteins (BMPs).[119,120] FDBA can be used in either a mineralized or demineralized form. Both FDBA and DFDBA contain BMPs; however, in the quantities used clinically, the amount of BMPs is generally inadequate to account for osteoconduction. Demineralization removes the mineral phase and purportedly exposes the underlying bone collagen and growth factors, particularly BMPs.[80,88,89]

Although the demineralization process exposes growth factors, it also destroys approximately half of the growth factors in FDBA. Additionally, the demineralization process removes the mineral portion of the graft (hydroxyapatite), which is critical for maintaining the matrix of the grafted site and providing for osteoconduction. Several authors have since challenged this theory based on unpredictable results with DFDBA, suggesting that these al-

lografts may contain inconsistent and often inadequate levels of BMPs because of handling and processing.[121-126] One study suggested that using DFDBA in combination with hydroxyapatite may somewhat improve its effectiveness.[110] These concerns are valid; hence, the author recommends FDBA rather than DFDBA for bone grafting.

Irradiated cancellous bone has also been used as a substitute graft material for autogenous bone.[90,91] However, using mineralized FDBA provides a local substrate of mineral for the graft and no BMPs are destroyed in the demineralizing process. Jensen and Greer found that radiated mineralized allografts used in conjunction with maxillary antroplasty, a screw-form implant, and an expanded polytet rafluoroethylene (e-PTFE) membrane barrier provided more predictable ossification than demineralized cancellous allograft.[105] They concluded that this graft material was the best option other than autogenous bone.

Advantages of allografts include ready availability, minimum autogenous bone harvested from the patient, reduced anesthesia and surgical time, decreased blood loss, and fewer complications.[83] The disadvantages are primarily diminished capacity to produce bone as compared to autogenous bone, and perhaps the theoretical disadvantages associated with tissues transplanted from another individual[80,83,96] Cadaver bone can be rejected like other transplanted tissues or organs. Technical problems include the precision required to insert bulk allografts, the necessity for rigid fixation to the host bone to obtain successful union, and the high rates of infection, nonunion, and graft fracture.[80,87] Because allografts are not osteogenic, adding this material to autogenous bone means that bone formation will proceed more slowly and result in less volume than with purely autogenous grafts.[83] Studies have shown that DFDBA for the maxillary sinus is often not completely remodeled by the host and does not always produce sufficient or quality new bone, even when a protective membrane is used.[1,105,106]

Alloplasts

Alloplasts, which may be natural or synthetic, heal only through osteoconduction. The most commonly used alloplasts are bioactive ceramics, which include synthetic calcium phosphate materials (e.g., hydroxyapatite) and those derived from natural sources (e.g., deorganified bovine bone). Ceramics such as hydroxyapatite are safe and well tolerated but have little ability to encourage new attachments.[94] Nonresorbable hydroxyapatite has also been criticized as being of modest value for grafting the maxillary sinus for implants.[127,128] Calcium phosphate ceramics act primarily as filler materials, with new bone formation taking place along their surface.[95,96] They can help provide a scaffold for enhanced

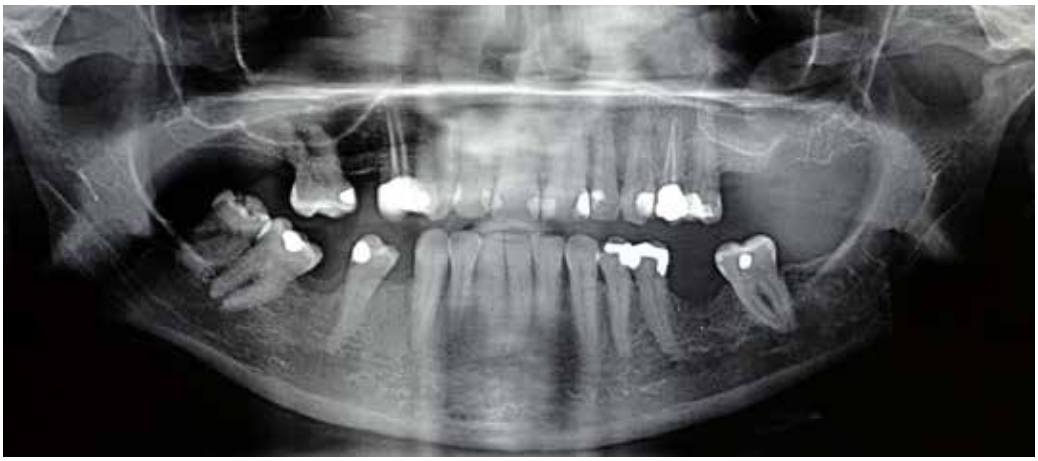


Fig. 4-5

The panoramic radiograph is the main radiographic tool for initial assessment of the maxillary sinus.

bone tissue repair and growth. Combining allograft or alloplastic grafting material with autogenous bone can decrease the amount of harvested bone necessary for the sinus lift procedure,[7] but, as noted earlier, bone formation may be less complete or proceed more slowly than when autogenous bone is used alone.

Biologic Growth Factors and Bone Grafts

The application of BMPs and other growth factors is the subject of increased research as a way to enhance bone regeneration and possibly even to replace bone grafting altogether for inducing osteogenesis. For instance, Boyne et al and others have studied the efficacy, safety, and technical feasibility of delivering human recombinant BMP-2 via an absorbable collagen sponge implant in various vases.[22,129-133] In animal studies involving maxillary sinus augmentation,[129,132,134] some authors have reported that this technique resulted in significant new bone formation in the floor of the maxillary sinus and that the delivery system did not induce any significant immune or other adverse response.

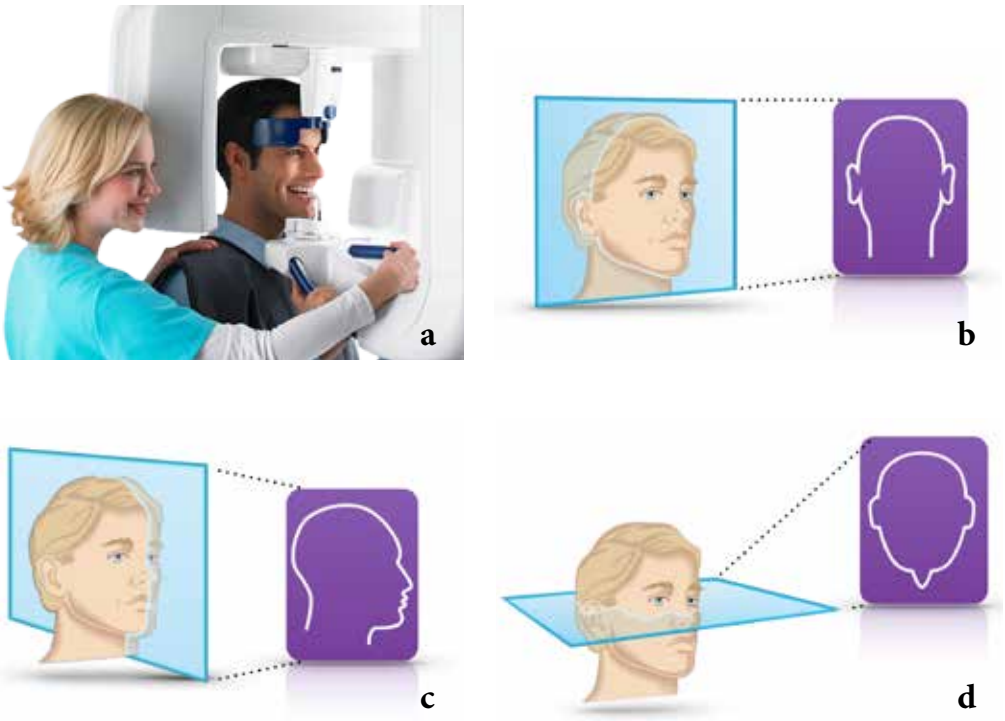
Preoperative Evaluation

Before sinus lift and grafting procedures, a thorough medical history must be obtained. In particular, the patient should be evaluated for seasonal allergies, allergic rhinitis, or sinus congestion upon waking, all of which may indicate sinus pathosis. A patient with sinusitis, sinus disease, or invasive lesions should be referred to an appropriate medical therapist for treatment before surgery. The patient should also be asked about tobacco use and the ability to refrain from use before and

Fig. 4-6

In some cases, the panoramic radiograph can be supplemented with CT scans to help determine the presence of anatomic variations such as septa and polyps.

The scanner takes images in an axial, a sagittal, and a coronal plane. This information can then be reformatted by the computer to provide images in a variety of formats.



after surgery, as such use can severely impact the success of bone grafting. Nicotine impairs bone healing, diminishes osteoblast function, causes autogenous bone graft morbidity, and decreases graft biochemical properties.[135-137]

To help the clinician determine the available maxillary alveolar bone height, the location of sinus floor convolutions (septa), and the surgical entry site, panoramic radiographs (Fig. 3-4) are necessary and can be supplemented with sinus radiographs and computed tomography (CT) scans (Fig. 3-6). An anesthesia light wand may also help to illuminate the sinus and to guide placement of the sinus wall osteotomy.[138-140] The wand is placed transnasally or in the palatal region intraoperatively. Postoperatively the wand can be used to evaluate the density of graft material in the sinus prior to closure since it illuminates any voids or uneven placement of the graft material.

Interdental space is evaluated for the available space between the gingiva and the proper plane of occlusion, which should be greater than 5 mm. Less than 5 mm of vertical space for prosthetic reconstruction requires a gingivectomy, a vertical osteotomy of the maxillary posterior alveolar process, and/or correlation of the mandibular plane.[13,21] If more than 20 mm of vertical space is available for prosthetic reconstruction, ridge augmentation in addition to sinus grafting should be considered. The clinician must deter-

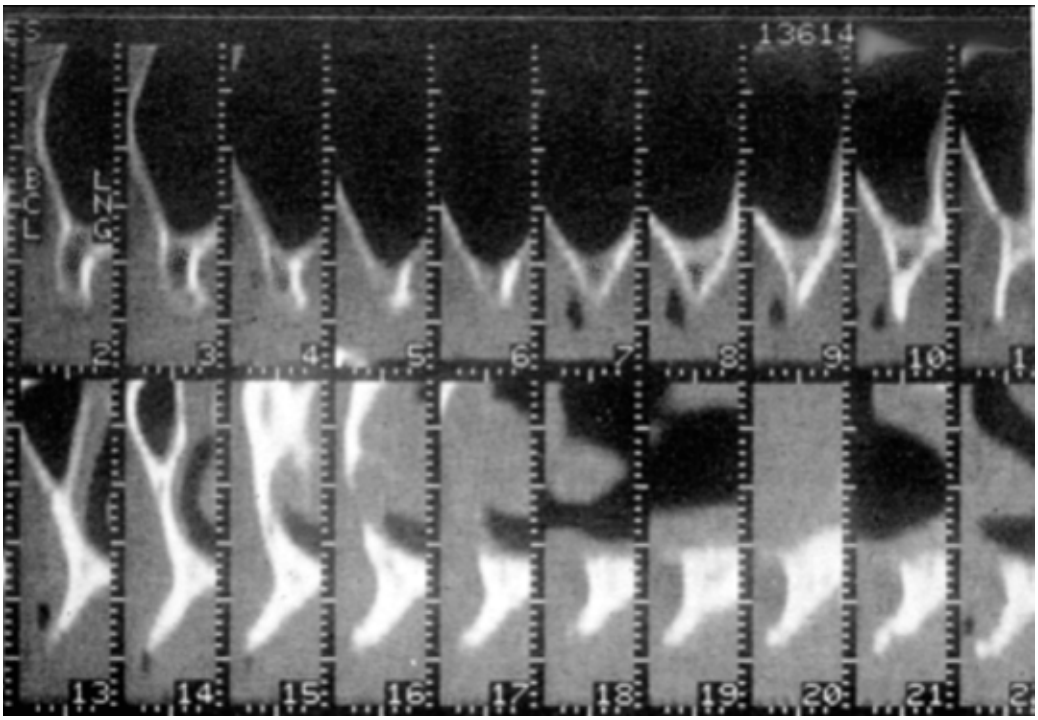


Fig. 4-7

A tomographic image in which specialized software was used to provide slices perpendicular to the facial aspect of the maxilla. The anterior maxillary ridge, posterior maxillary ridge, and maxillary sinus can be seen in the various images.

Looking at the relative radiolucency of the maxillary sinus in slice #3, and by looking at the relative radiopacity of the type 3 bone of the anterior maxilla in slice #16, one can compare the relative density of the spongy bone in slice #3. It is almost closer in appearance to the radiolucency of the maxillary sinus than it is to the type 3 bone.

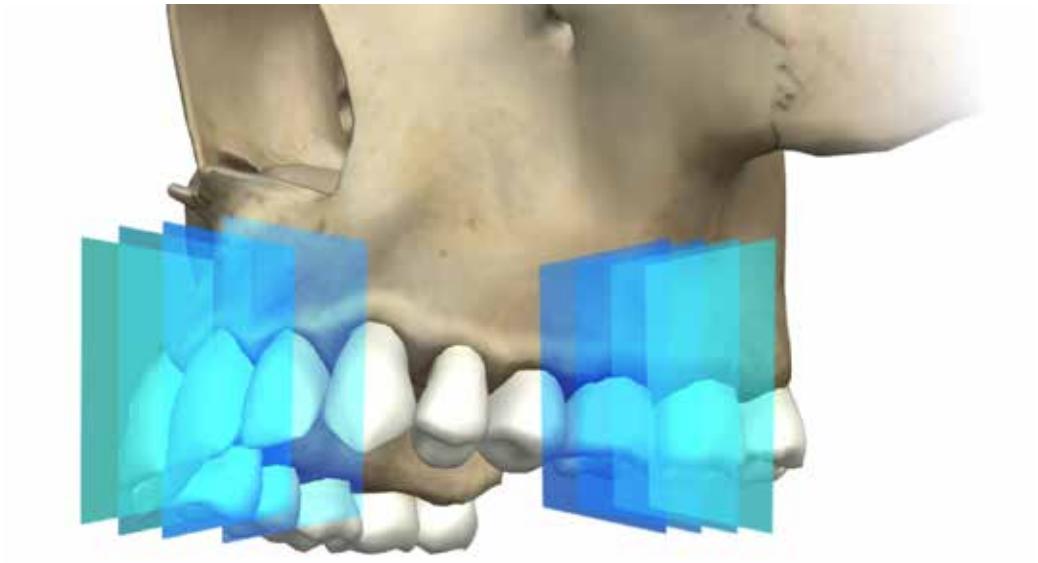


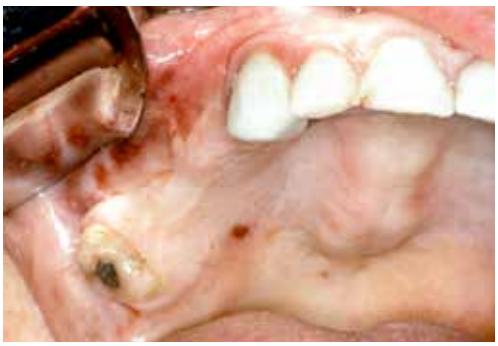
Fig. 4-8

mine if any active disease or disorders (such as acute sinusitis, retained root tips, polyps, tumors, cysts in the antral cavity) exist in the sinus. Patients with periodontal disease have an increased incidence of maxillary sinus disease, which may have an impact on implantation.[141-143] All remaining maxillary teeth should be evaluated for signs of periodontal disease extending from the tooth into the maxillary sinus. In the absence of such contraindications, and after the relevant patient workup has been completed, surgery can begin.

CHAPTER

5 Surgery Technique for Lateral Wall

Antibiotics effective against both aerobic and anaerobic bacteria should be administered preoperatively and continued for 7 to 10 days postoperatively.[10,144,145] The surgery can be performed with the patient sedated with intravenous medication unless the graft material is procured from the iliac crest, in which case general anesthesia should be used. A local anesthetic with a vasoconstrictor for hemostasis is infiltrated into the maxillary surgical site and any intraoral graft donor site. The surgery can also be performed with local anesthesia, posterosuperior alveolar, and greater palatine nerve blocks combined with infiltration. The clinician could also use second-division nerve block, entered from the greater palatine canal.



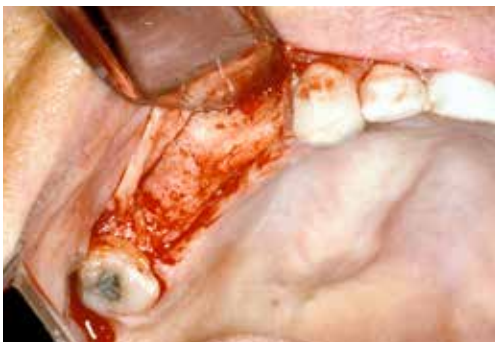


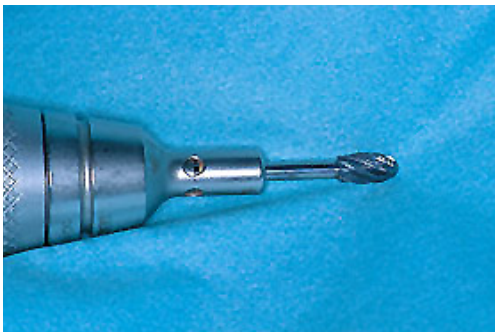
Fig. 5-1

A palatal incision is placed in this case for a maxillary sinus augmentation.

Lateral Wall Sinus Procedure

A horizontal incision is made on the crest or palatal aspect of the edentulous ridge, with extensions beyond the areas of the osteotomy and with consideration of the amount of attached gingiva on the alveolar crest. The incision is carried forward beyond the anterior border of the sinus (Fig. 5-1). A vertical releasing incision to the depth of the vestibule in the canine fossa area helps to reflect the flap and expose the bone; it also ensures good soft tissue closer over the bone. The lateral wall of the maxilla is exposed by reflecting the mucoperiosteal flap superiorly to the level of the malar buttress. Elevation of the periosteum adjacent to the implant site should be minimized to preserve the blood supply to the alveolar crest. The periosteum should be reflected superiorly just beyond the height of the superior aspect of the anticipated opening into the maxillary sinus (approximately at the level of the zygoma).

After the lateral maxillary wall has been completely exposed, a no. 8 round diamond bur should be used in an oval configuration at low speed and high torque to make an oval osteotomy in the lateral wall of the maxillary sinus (Fig. 5-2). If the maxillary wall is thick, a no. 8 round carbide bur can be used to initiate the osteotomy (to cut more quickly) and then exchanged for a diamond bur of the same size and shape as the Schneiderian membrane is approached in order to minimize the risk of perforating the membrane with the bur. Slight variations in osteotomy technique have been described: some authors[30] create a U-shaped osteotomy with the vertical arms of the osteotomy parallel to the facilitate infracturing, and others[1] make a trapezoid-shaped osteotomy with a no. 1701 fissure cut bur. An oval-shaped oste-



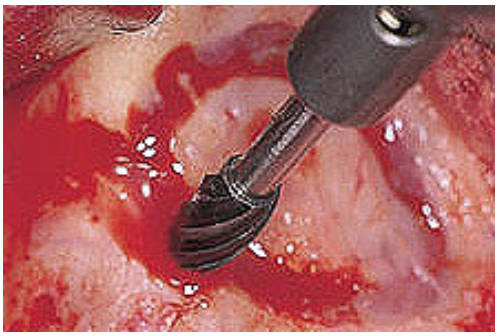
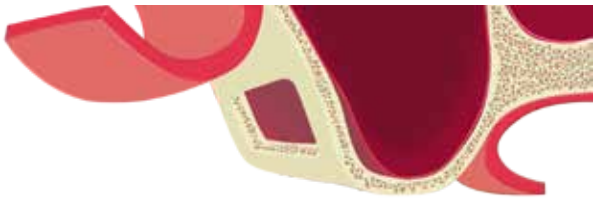
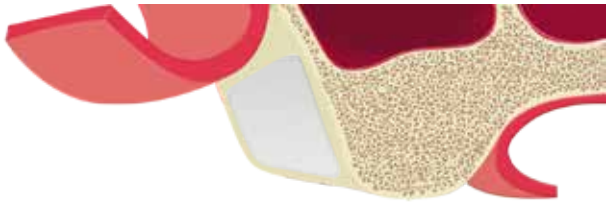


Fig. 5-2

Large carbide burs, small carbide burs, or #8 round burs are commonly used to begin the maxillary sinus osteotomy.





otomy is recommended to avoid sharp edges that may tear the Schneiderian membrane.[24] Similarly, the round diamond bur is recommended to minimize perforations of the Schneiderian membrane. A brush-stroke touch is used to penetrate the bone and avoid the Schneiderian membrane. To ensure that the bone has been penetrated all the way around the oval osteotomy, the clinician should tap the bone gently, and any movement should be noted. The bone can be either pushed in to serve as the roof of the graft or removed to create a window for better visualization and access. In cases in which a septum is attached to the bone window, the window can be drilled down and obliterated so that the sinus is separated into two or more smaller chambers by the septum (Fig. 5-3).

At this point, the underlying Schneiderian membrane is exposed. Extreme care should be taken to reflect the membrane superiorly without perforating it. A curette is gently introduced along the margin of the created access window, with the curved portion placed against the Schneiderian membrane and the sharp edges placed against the bone (Fig. 5-4). The curette is slid along the bone, 360 degrees around the margin of the access win-

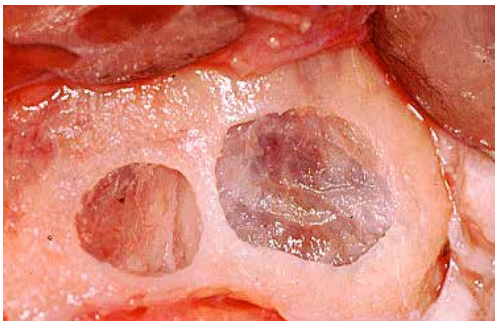


Fig. 5-3

When a large septum is present the best option is to create separate windows anterior and posterior to the septum.

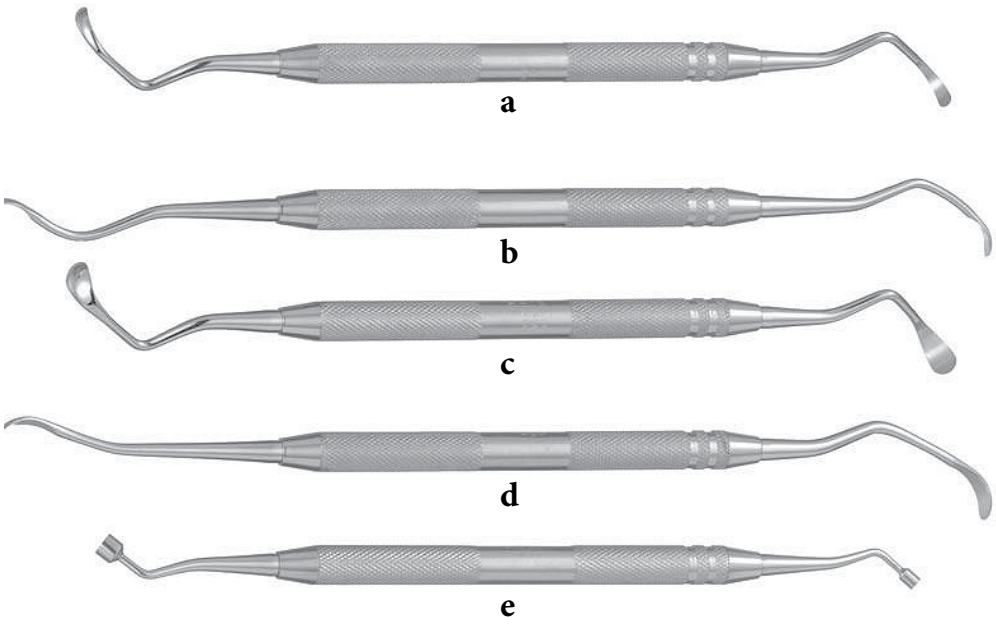


Fig. 45-4

a SLG1 - Sinus Lift Curette #1

b SLG2 - Sinus Lift Curette #2

c SLG3 - Sinus Lift Curette #3

d SLG4 - Sinus Lift Curette #4

e GAR3/5 3mm/5mm Plugger

Fig. 5-5

Lateral Wall Sinus Lift - Conventional Technique

a Crestal incision slighty to the palate.

b The buccal releasing incision is connected with the horizontal palatal incision (I).

c The buccal releasing incision is connected with the horizontal palatal incision (II).

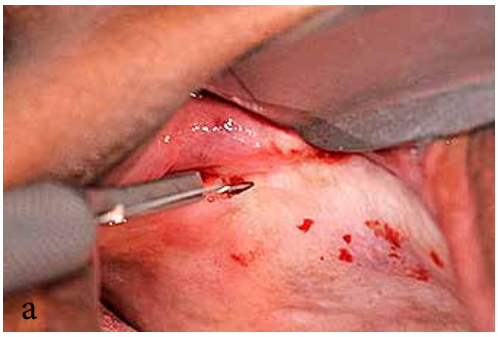
d Right side full-thickness flap refection.

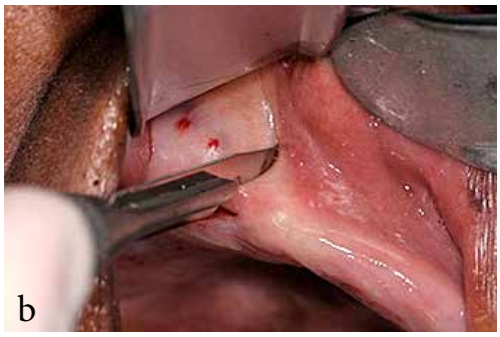
e Initial osteotomy using a round diamond bur (I).

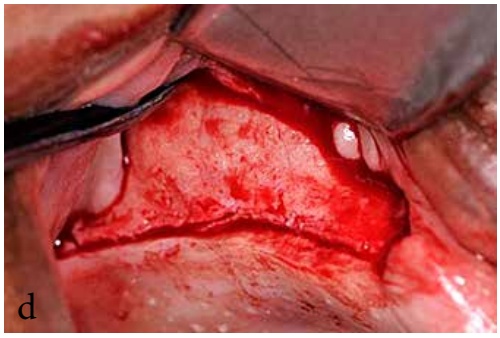
f Initial osteotomy using a round diamond bur (II).

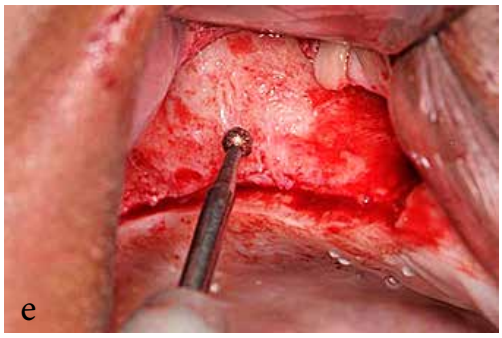
g Final osteotomy. Notice the vertical oval shape.

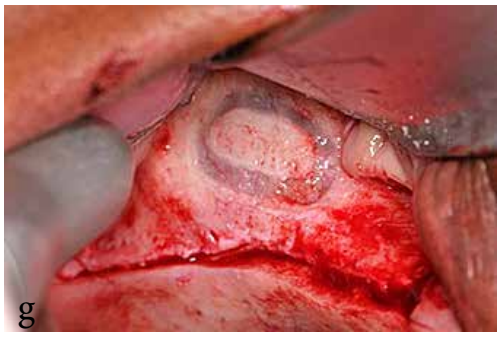
h Initial detachment of the membrane using a sinus curette.

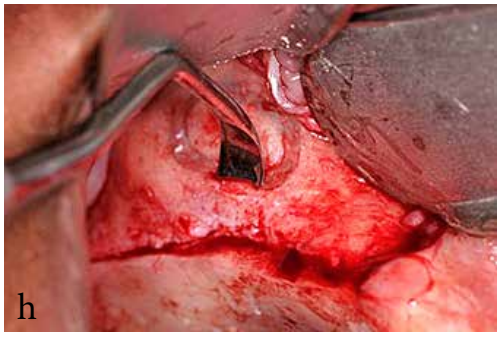


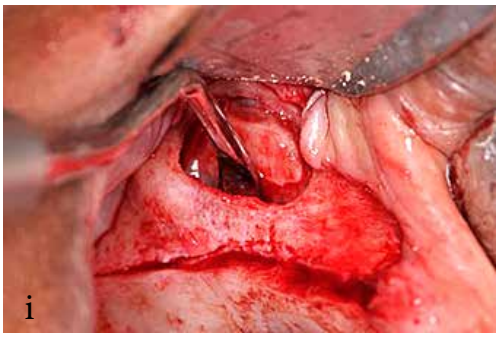


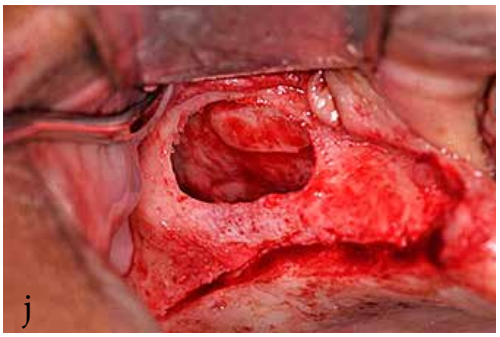












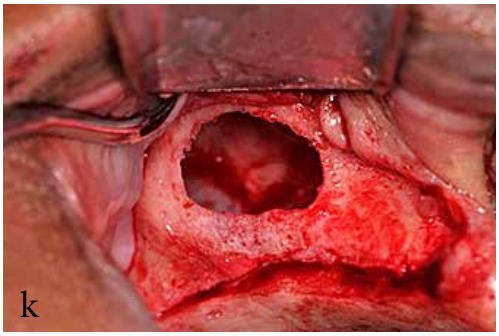


Fig. 5-5 (cont'd)

i While holding the curette in permanent contact with the bony floor of the sinus, light pressure is exerted inwards looking for the medial wall.

j Initial detachment of the sinus membrane completed.

k Final detachment of the sinus membrane completed.

l The cortical-cancellous allogenic bone graft is poured in a mixing cup (I).

m The cortical-cancellous allogenic bone graft is poured in a mixing cup (II).

n The cortical-cancellous allogenic bone graft is poured in a mixing cup (III).

o The PRP is added in the cup and mixed with the bone graft.

p The mix is progressive loaded in a tuberculin syringe (I).

dow. The Schneiderian membrane is then carefully elevated from the floor inferiorly, anteriorly, and posteriorly through the osteotomy sites. In the case of an extremely small window, the process should be performed with a sufficiently small curette. For the usual sinus window, the largest possible curette should be used to minimize the chances of perforating the Schneiderian membrane and to maximize the efficiency of the membrane-reflection process.

Perforation of the Schneiderian membrane during surgery most often occurs if the lateral wall is being infractured, but it can also happen when the membrane is being elevated from the inferior and anterior bony aspects of the sinus. The most common areas of perforation are at the level of the inferior osteotomy, the level of the greenstick fracture if used, and the inferomedial portion of the sinus window.[1] For small perforations in the membrane, a small piece of a collagen membrane

can be placed in the area to adapt to the perforation, occlude it, and allow it time to heal and repair itself.[1] For larger perforations, a longer-lasting, stiff, collagen-based membrane should be shaped into a dome and placed in the sinus to occlude the perforation and contain the graft. The clinician must ensure that all of the Schneiderian membrane has been reflected from the sinus floor so that the bone graft is lying on raw bone and not the epithelium.

The sinus floor septa (convolutions) are not necessarily altered. A vari-

able number of septa (also referred to as the Underwood septa) divide the floor of the maxillary sinus into several recesses and may complicate sinus lift procedures.[146-149] Most of the septa are located in the region between the second premolar and the first molar. Septal formation may be caused by the different phases of maxillary sinus pneumatization of the empty alveolar process following tooth extraction. To minimize the chance of complications from a septum, the clinician should create the inferior portion of the osteotomy at least 3 mm above the sinus floor and avoid it. If a septum is present and is higher than 3 mm from the floor (something that should be noted preoperatively because it will affect the surgery), the oval-shaped osteotomy should be split into three by the clinician's making vertical cuts through the bony window just anterior and just posterior to the septum. This process will create bony windows over the left and right compartments that are lifted off and a bony window over the septum that is not lifted off but rather is ground down with the drill and diamond bur.

Intraoperative Bleeding

Because there are no major vascular structures in the surgical area, any intraoperative bleeding that does occur usually comes from capillary soft tissue or bony ooze. The interconnecting vascular contributions to the maxilla and maxillary sinus likely account for the forgiving nature and rapid healing of maxillary sinus surgery; however, the vascular system can produce a brisk intraoperative oozing usually related to the patient's systemic blood pressure or local inflammation and only rarely to a bleeding disorder or coagulopathy. Most hemostatic disorders have already been diagnosed by the time a patient reaches the age when a sinus lift would be required, or else such disorders are noted by the clinician while obtaining a thorough preoperative history. For patients who claim to be "bleeders" or who have a suspicious history of bleeding problems, a simple battery of screening blood tests will identify 98.5% of bleeding disorders. This series of tests includes a complete blood count (CBC) with a platelet count and differential, a bleeding time test, a prothrombin time, and a partial thromboplastin time.

If brisk intraoperative oozing develops, the patient's systemic blood pressure should be checked. Hypertension control is usually established by reinforcing the local anesthesia, verbally reassuring the patient, and using additional sedation if necessary. It is rare but possible that a procedure may have to be stopped because of uncontrollable hypertension. Locally brisk oozing is best controlled by temporarily packing the wound (Fig. 4-6). Saturating the packing with 2% lidocaine with 1:100,000 epinephrine or 4% liquid cocaine will sometimes assist hemostasis, particularly if the oozing is from soft tissue. If the oozing is from bone

Fig. 5-5 (cont'd)

q Initial grafting of the sinus cavity(I).

r Bone is delivered into the distal part of the sinus cavity.

s Delivery of graft in the central part of the sinus cavity (I).

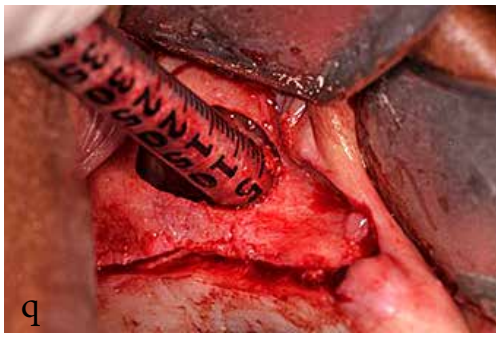
t Delivery of graft in the central part of the sinus cavity (II).

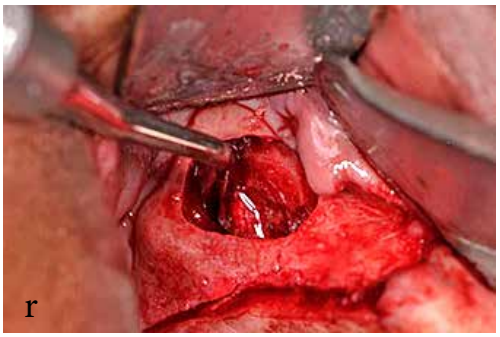
u Sinus cavity fully filled

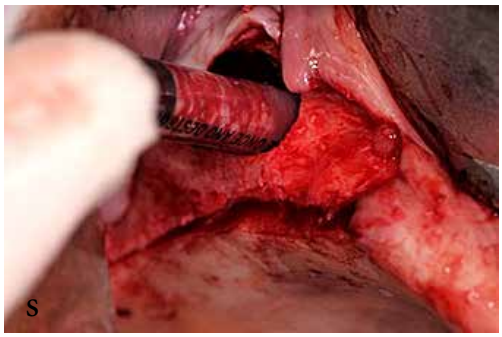
v A PRP membrane ready for use.

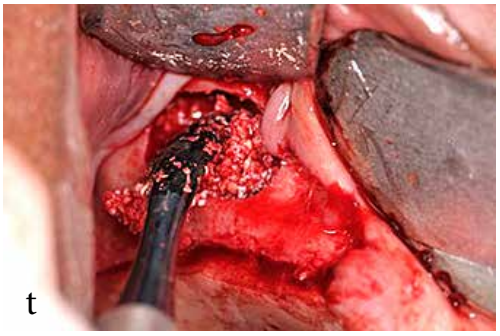
w Coverage of the graft with a PRP membrane.

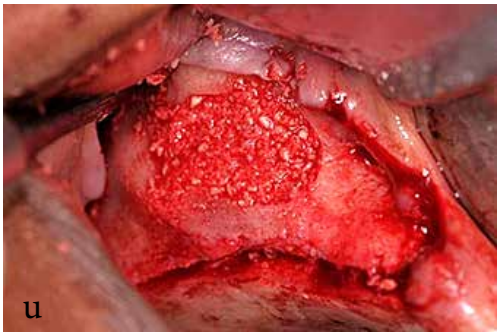
x Flap repositioned in place by single interrupted sutures.

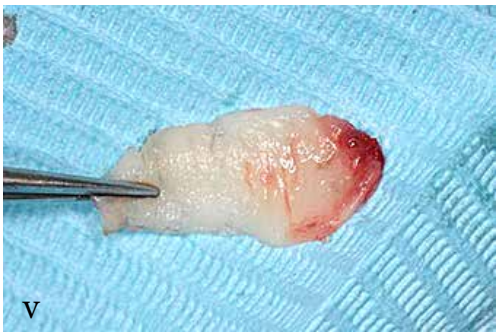


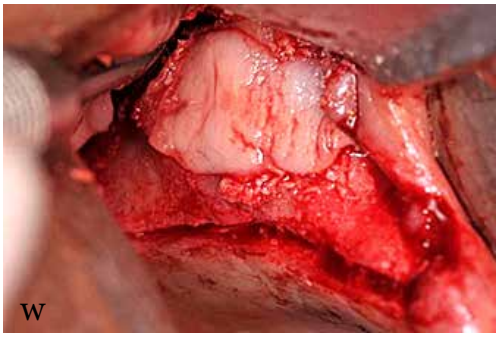












and cannot be controlled with temporary packing, pressing bone wax into the area is usually effective. In addition, microfibrillar bovine collagen (Avitene, MedChem Products, Woburn, MA) is an excellent resorbable and compatible agent that initiates clot formation. Two additional "leave-in" agents, Gelfoam (Pharmacia and Upjohn, Kalamazoo, MI) and Surgicel (Johnson & Johnson, New Brunswick, NJ), also assist in clot formation and hemostasis. However, the most effective means is to use Avitene for slower-paced bony oozing and bone wax for more rapid oozing.

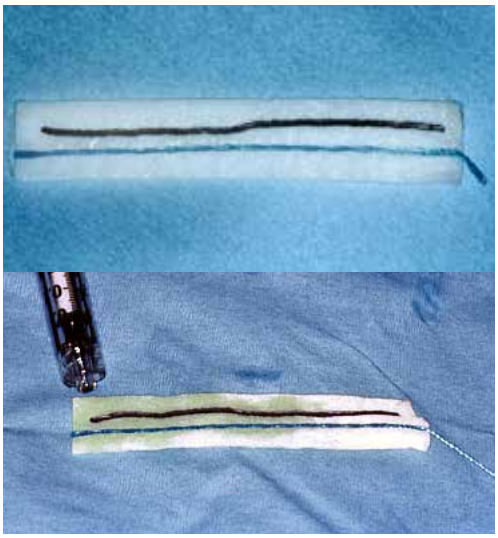
Grafting Procedure

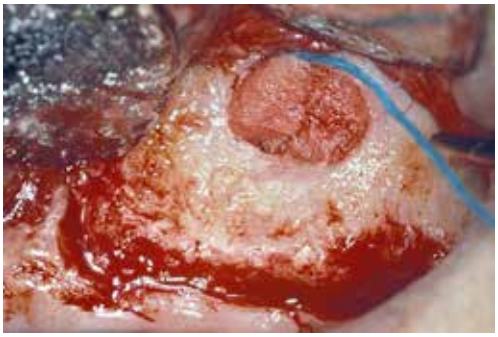
During the sinus lift grafting procedure, autogenous bone is harvested from the preselected site and, if appropriate, mixed with other graft materials. This mixture is then packed and compacted into 1-mL or 3-mL syringes and set aside. As described earlier, a one-step procedure can be performed, with the graft and implant placed simultaneously. When this approach is selected, essential surgical modifications will be necessary, including a wide lateral window opening, a bone mill to homogenize the graft material, meticulous condensation of the graft, and clinical measurements to ensure implant parallelism.[61] The implant sites should be drilled with a surgical stent as a guide. It is important to protect the sinus membrane during this procedure. After the clinician prepares the implant sites, the top of the syringes should be cut off with scissors and the graft mixture injected into the maxillary sinus and packed against the intact medial wall.

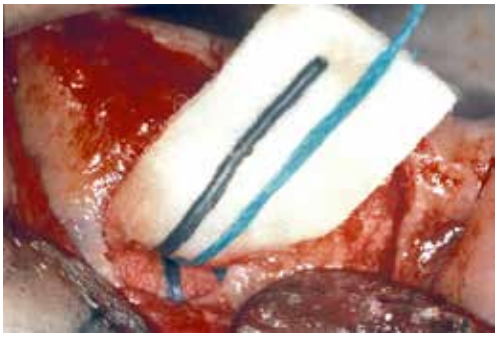
After the clinician grafts the medial portion of the sinus, the implants are placed. Bone is then packed against the anterior and posterior maxillary walls, molding the bone against and over the implant to a height of 10 mm to 12 mm. The clinician must maintain the implant in the proper position to avoid compromising subsequent prosthetic restoration. Next, the lateral portion of the surgical site should be firmly packed with the bone graft. If the diameter of the implant is greater than the width of the alveolar crest, bone should be placed and secured outside the sinus against the lateral surface of the implants. The area of the access window should then be covered with a membrane barrier to prevent soft tissue ingrowth, the mucoperiosteal flap should be repositioned, and the incisions should be closed with interrupted sutures. The graft can mature while the implant is integrating.

If a two-step surgical approach is used (i.e., separate grafting and implant placement surgeries), adequate graft material is placed in the maxillary sinus to accommodate the length of the implant. The window is then covered with a resorbable membrane barrier, as with the one-step procedure. The mucoperiosteal flap is repositioned, and

Fig. 5-6







Three Principle Benefits
Gauze Saturated With Hemostatic Agent Decreases Oozing or Bleeding
Provides Additional Reflection of Schneiderian Membrane (Approximately 10-30 Percent) **Do NOT overpack**
Approximation of Reflected Sinus Volume

the incisions are closed with interrupted resorbable sutures. After the bone has matured (approximately 4 to 12 months depending on the graft materials used, the graft size, and the patient's systemic health), it is evaluated to ensure that there is sufficient bone height for implant placement. The implants can then be placed in the mature graft material following the surgical protocol prescribed for that system and allowed to integrate.

Clinical Cases

Figures 5-7 to 4-30 present several cases demonstrating the lateral wall pro-

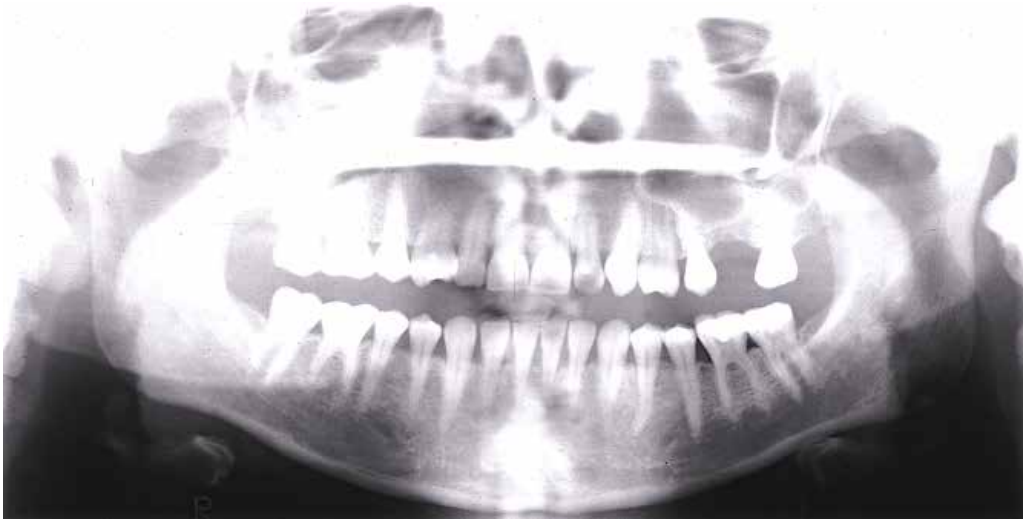
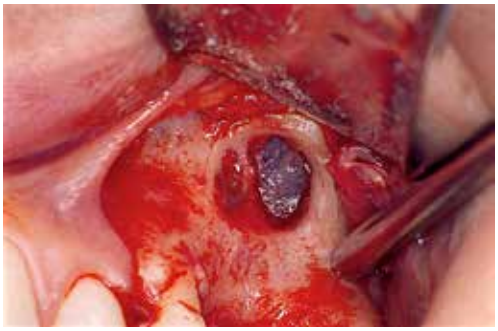
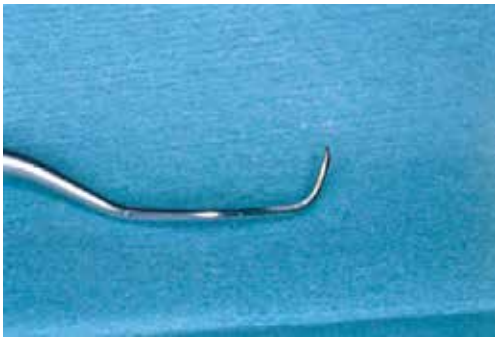


Fig. 5-7

In this case of a missingsingle tooth, a lateral wall sinus lift is performed. With the septum present a chamber is created anterior and a separate chamber posterior to the septum.





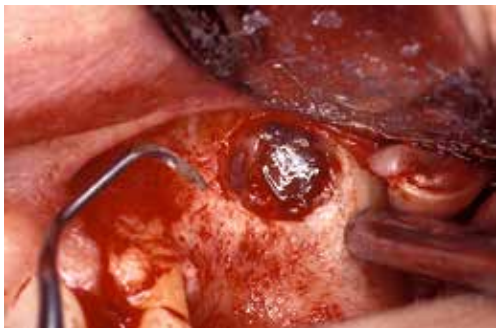
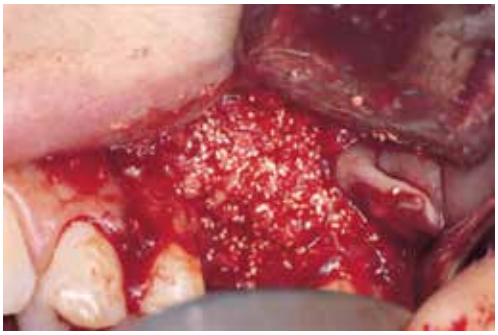


Fig. 5-7 (cont'd)

FDBA bone is mixed with bone shavings and PRP and grafted into the sinus



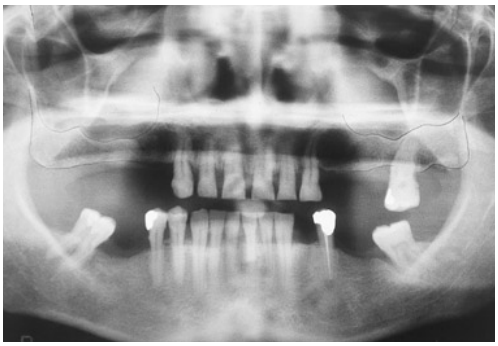
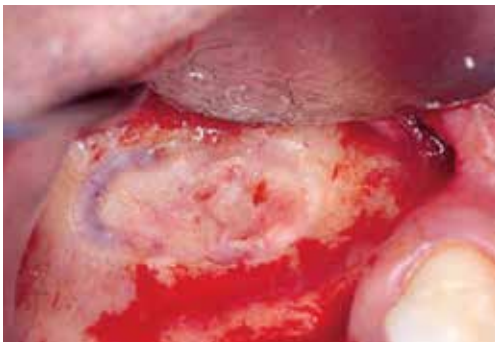
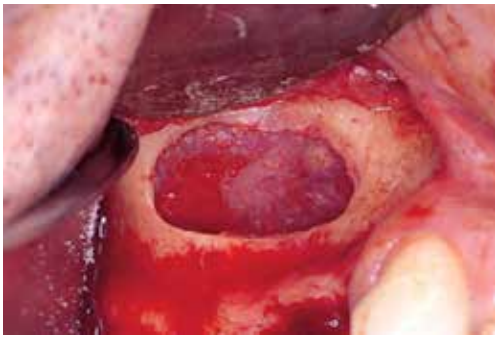
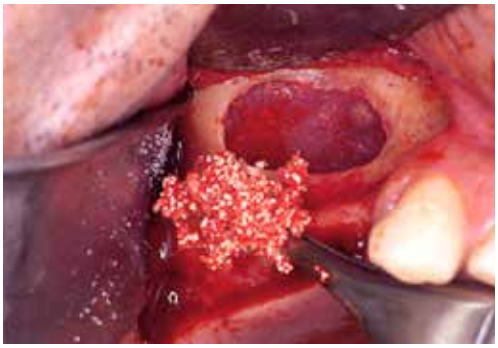
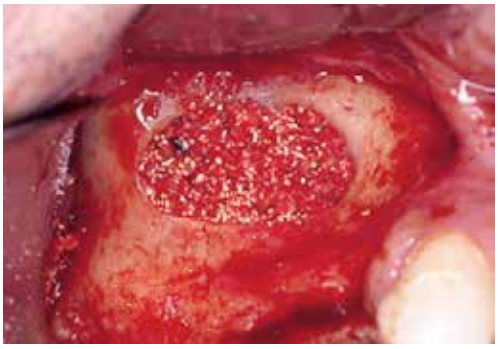
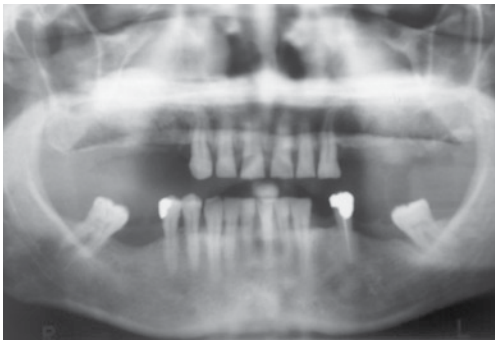







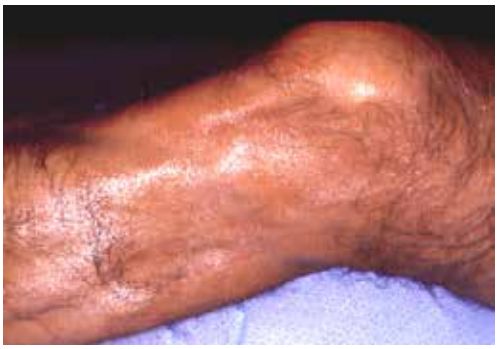
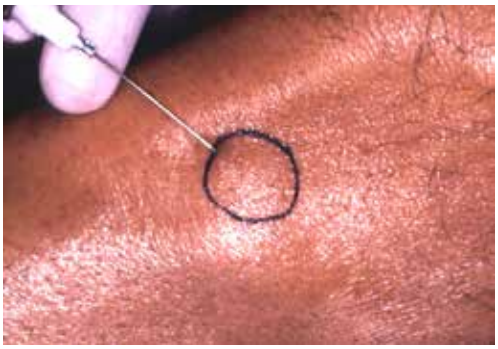
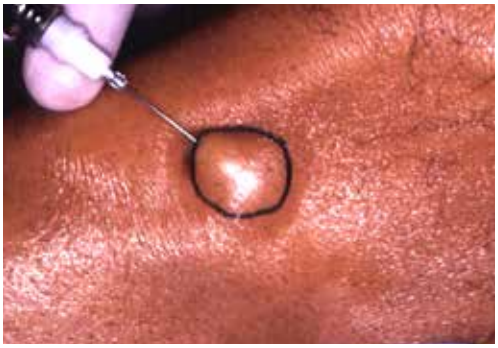
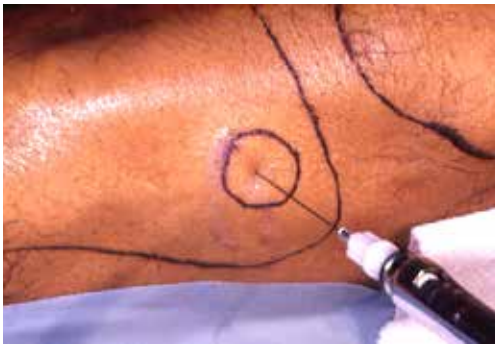
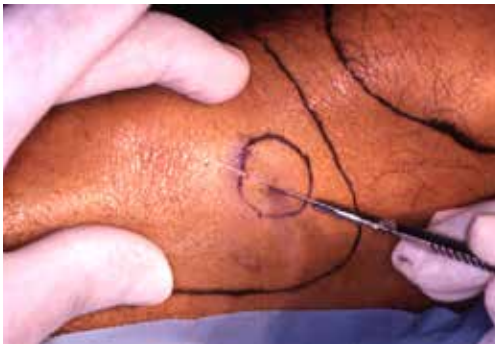
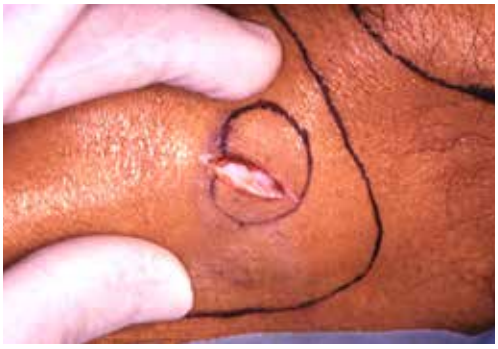
Fig. 5-8

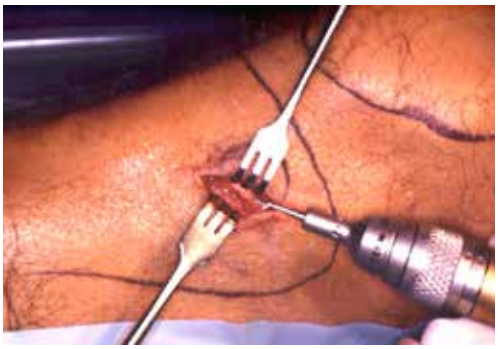
Partially Edentulous in Posterior Maxilla Bilaterally.

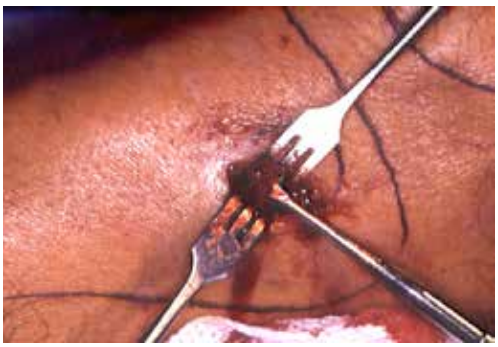
Bilateral sinus graft is performed.

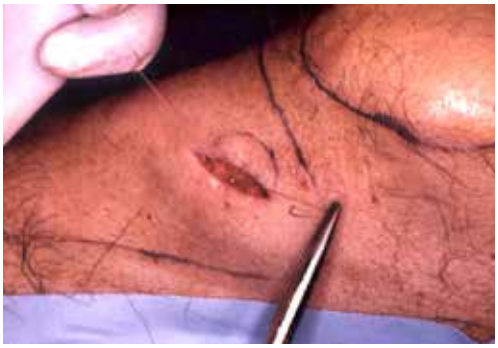
Fig. 5-9

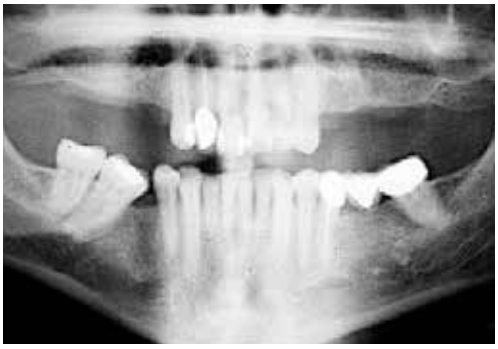
Bilateral Sinus Grafts
Tibial Bone Harvest
PRP
IV Sedation
Staged Placement of 10 Implants









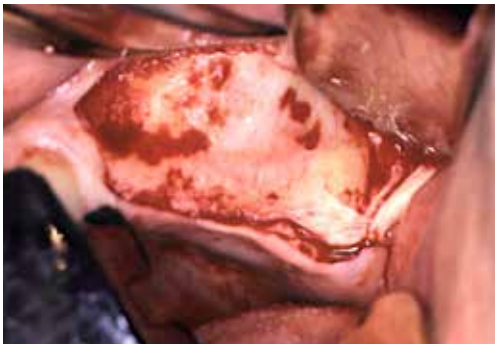
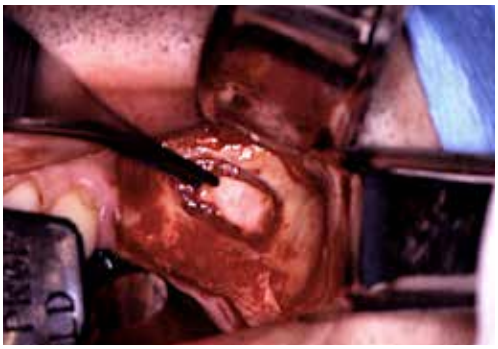
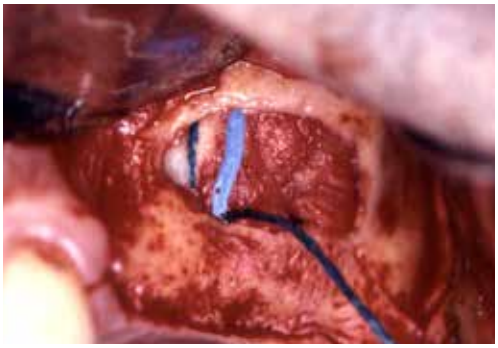
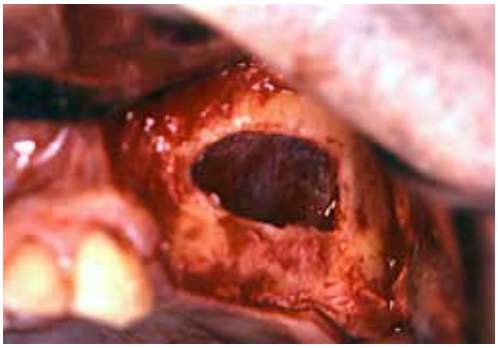
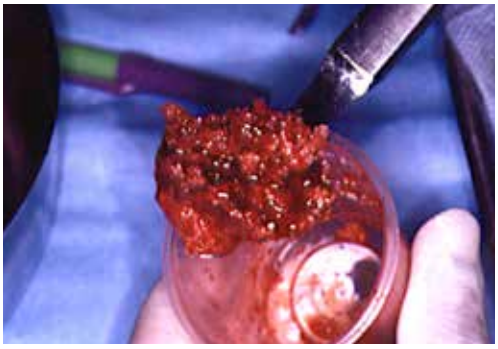
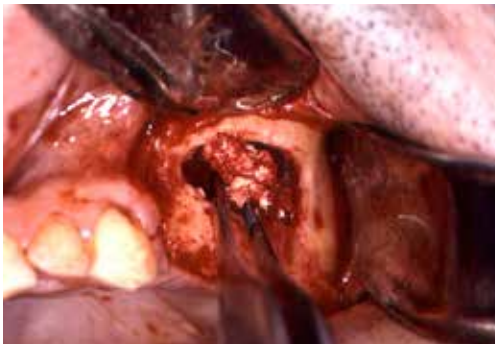


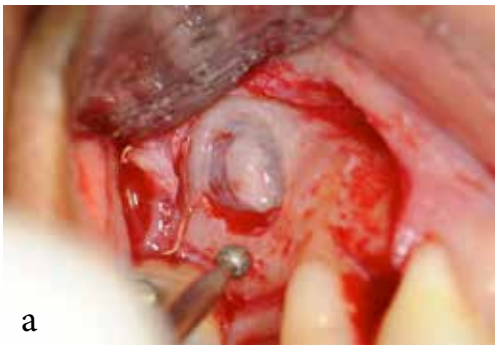
Fig. 5-9 (cont'd)

Bilateral Sinus Grafts
Tibial Bone Harvest
PRP
IV Sedation
Staged Placement of 10 Implants

Fig. 5-9 (cont'd)

Bilateral Sinus Grafts
Tibial Bone Harvest
PRP
IV Sedation
Staged Placement of 10 Implants



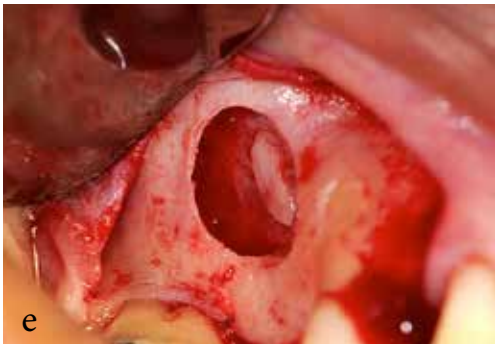


Fig. 5-10

Single Tooth Sinus Grafts

FDBA with Thick Carboxylmethyl cellulose Bone Binder

a Right side full-thickness flap reflection and initial osteotomy using a round diamond bur.

b Final osteotomy using a round diamond piezo tip.

c Initial detachment of the membrane (I).

d Initial detachment of the membrane (II)

e Final detachment of the membrane.

f Gauze strip ready for use.

Fig. 5-10 (cont'd)

g The gauze saturated with hemostatic agent is gently packed in the sinus cavity to control the bleeding.

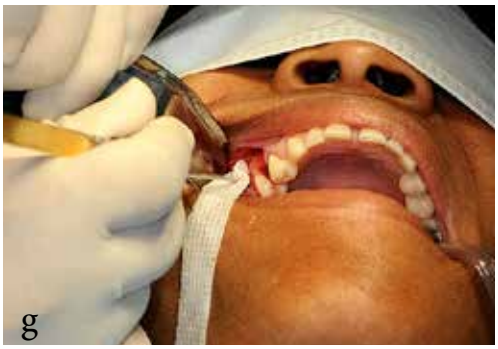
h The gauze also increases the reflection of the membrane and provides an approximation of the reflected sinus volume.

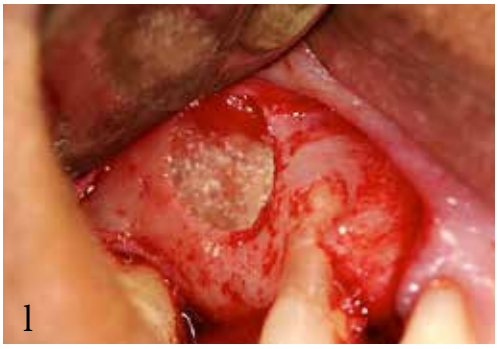
i The FDBA is mixed with carboxymethyl-cellulose bone binder to improve the handling of the graft.

j Initial filling of the sinus cavity.

k Graft material is gently compacted in all directions.

l Partial filling of the sinus cavity.





Notes

Fig. 5-11

a Crestal incision slighty to the palate (I).

b Crestal incision slighty to the palate (II).

c The buccal releasing incision is connected with the horizontal palatal incision.

d Full-thickness flap refection.

e Initial osteotomy using a round diamond piezo tip.

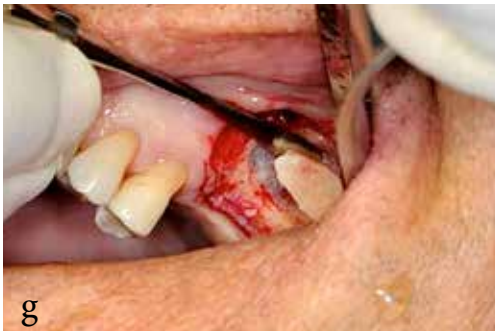
f Final osteotomy. Notice the vertical oval shape.

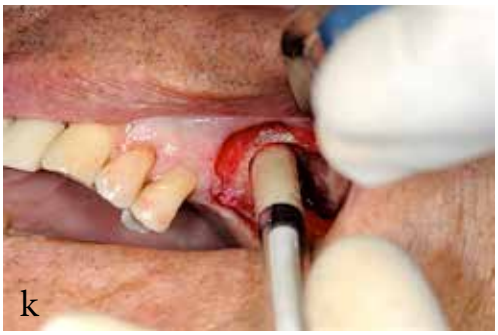
g Removal of the central bone of the osteotomy.

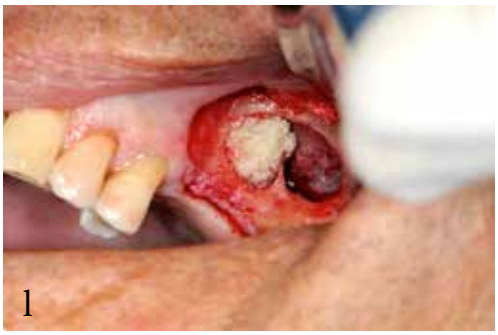
h Initial detachment of the membrane using a trumpet piezo tip.

i Initial detachment of the sinus membrane completed.

j The antral cavity will be grafted with a cortical-cancellous allogenic bone graft only.







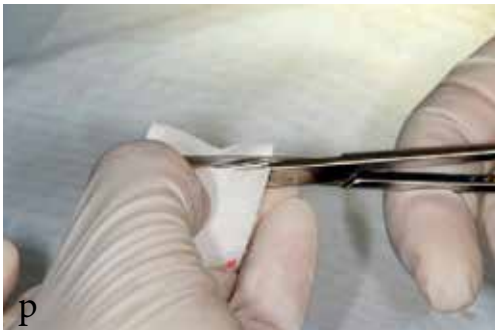


Fig. 5-11 (cont'd)

k The graft is delivered into the sinus cavity using a tuberculin syringe.

l Initial filling of the sinus cavity.

m Graft material is gently compacted in all directions.

n Antral cavity fully filled.

o The central bone of the osteotomy is repositioned in place.

p Trimming of the membrane.

q Coverage of graft material with a resorbable xenogenic collagen membrane.

r Flap repositioned in place by single interrupted sutures.

Notes

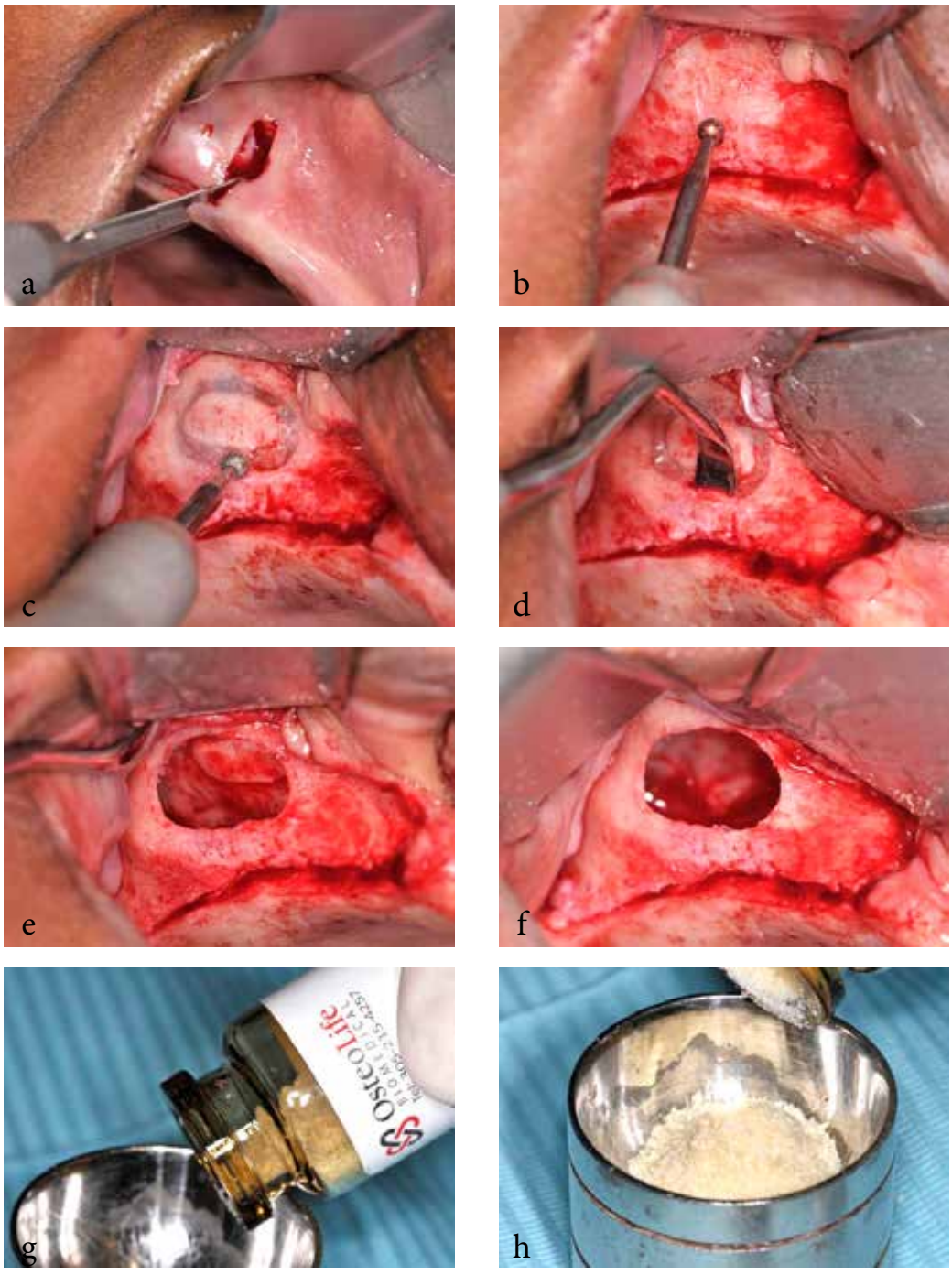


Fig. 5-12

a The buccal releasing incision is connected with the horizontal palatal incision.

b Full-thickness flap refection.

c Final osteotomy. Notice the vertical oval shape.

d The sinus membrane will be detached with an specifically designed angled curette.

e Initial detachment of the sinus membrane.

f Final detachment of the sinus membrane.

g The antral cavity will be grafted with a cortical-cancellous allogenic bone graft.

h The graft is poured in a mixing cup.

Fig. 5-12 (cont'd)

i The PRP is suctioned into a syringe.

j The PRP is added to the graft.

k The PRP is mixed with the graft in the mixing cup.

l A PRP membrane is also obtained from the patient's own blood.

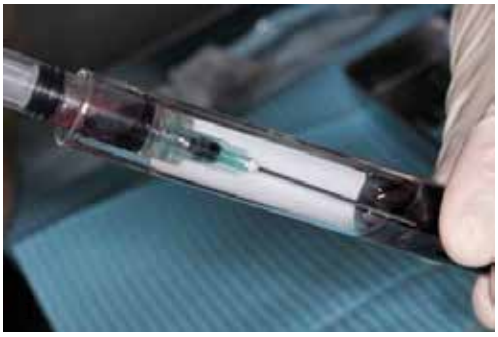
m The mix bone/PRP is delivered into the antral cavity.

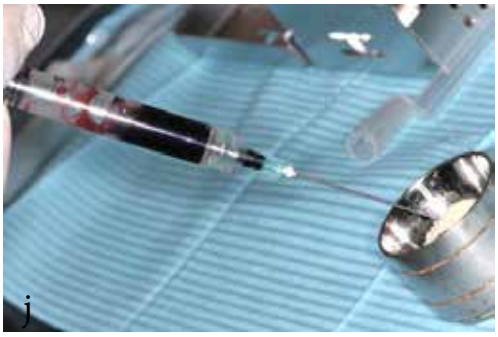
n Antral cavity fully filled.

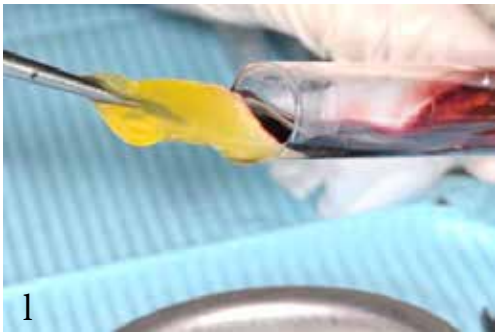
o The PRP membrane compressed and ready for use.

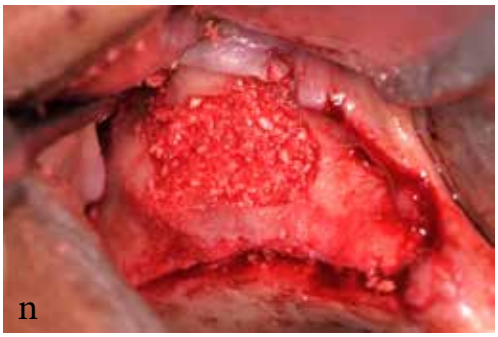
p Coverage of the graft with a PRP membrane.

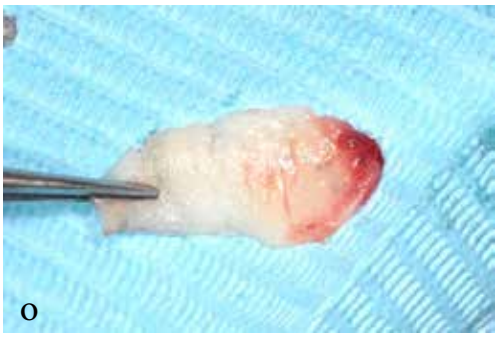
q Flap repositioned in place by single interrupted sutures.

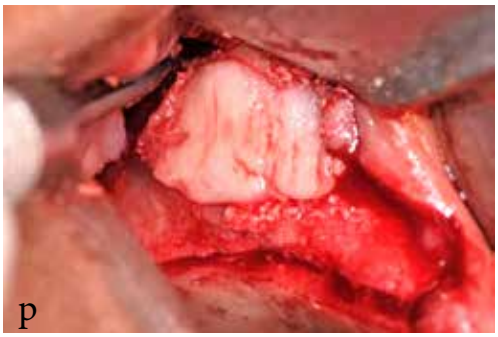












Notes

Fig. 5-13

a Radiographic pre-operative view.

b Clinical pre-operative view.

c Initial osteotomy. Notice the vertical oval shape.

d Final osteotomy and membrane detachment.

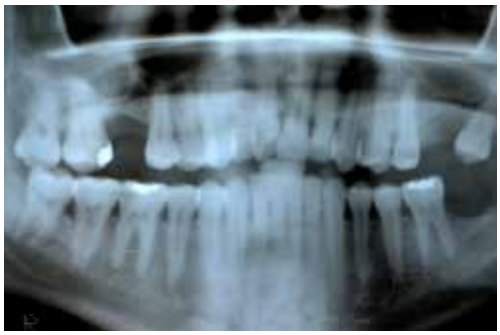
e Antral cavity fully filled with cortical-cancellous allogenic bone graft.

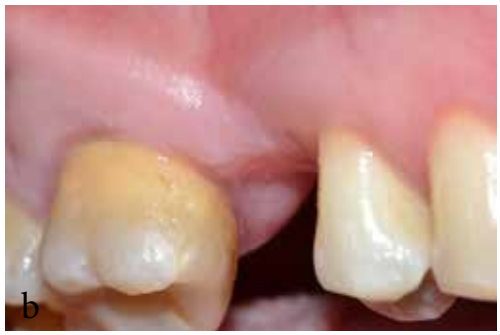
f Coverage of graft material with a resorbable xenogenic collagen membrane.

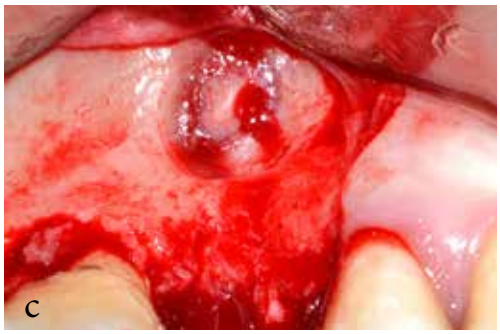
g Implant placement after a 6-month healing period.

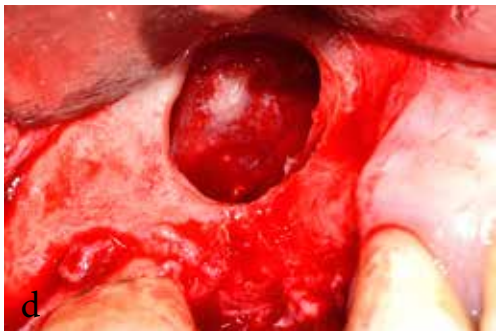
h Radiographic post-operative view after crown cementation.

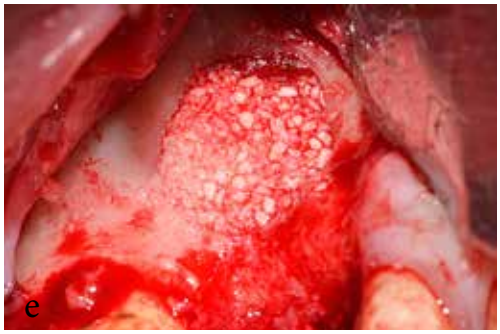
i One-year clinical post-operative follow-up view.

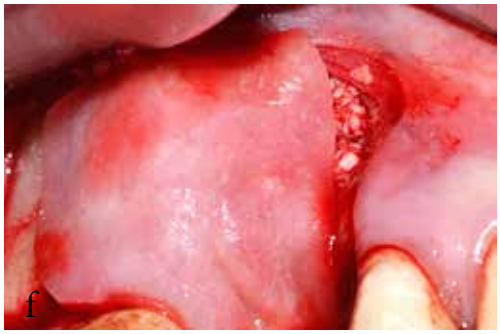


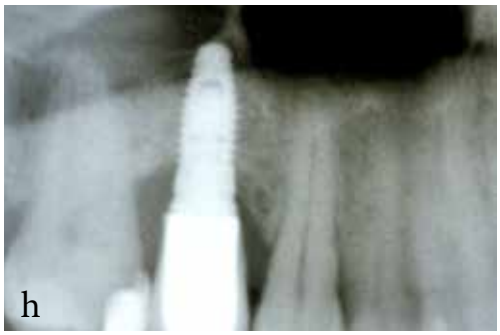


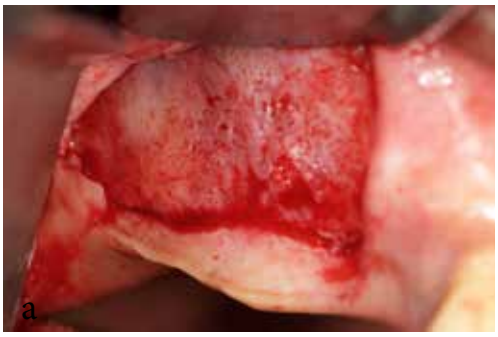


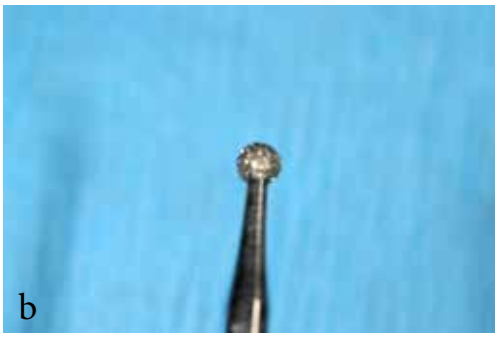


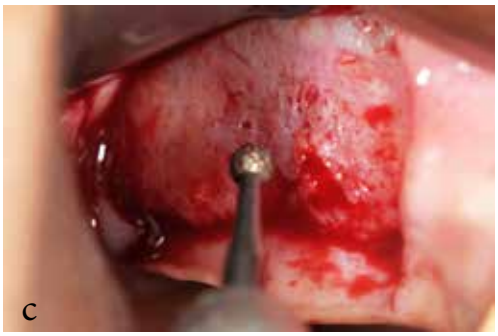


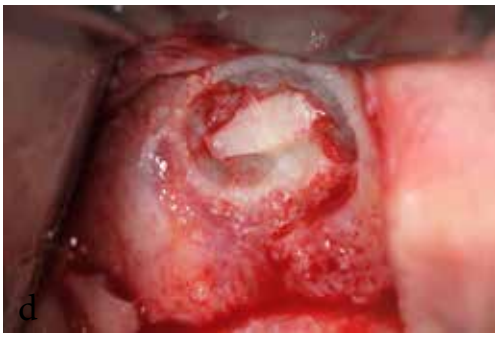












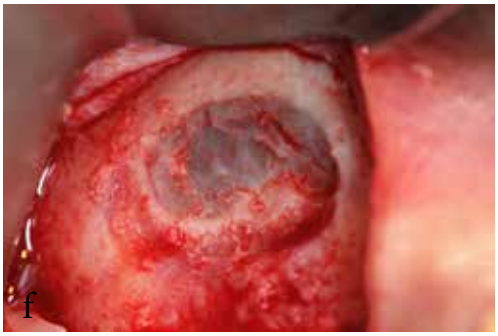


Fig. 5-14

a Full-thickness flap refection.

b Round diamond bur used for the osteotomy (I).

c Round diamond bur used for the osteotomy (II).

d Initial osteotomy. Notice the round shape.

e Removal of the central bone of the osteotomy.

f Final osteotomy.

g Initial detachment of the membrane using a trumpet curette tip (I).

h Initial detachment of the membrane using a trumpet curette tip (I).

Fig. 5-14 (cont'd)

i Initial detachment of the membrane from the upper side.

j Initial detachment of the membrane from the mesial side.

k Initial detachment of the membrane from the sinus floor.

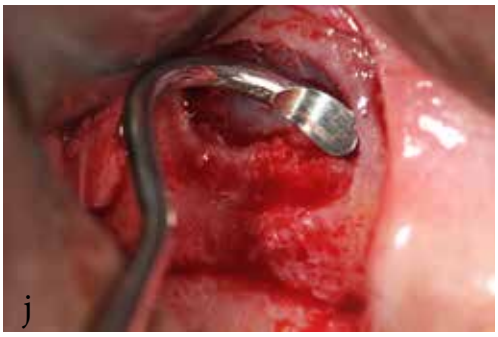
l Completed detachment of the sinus membrane.

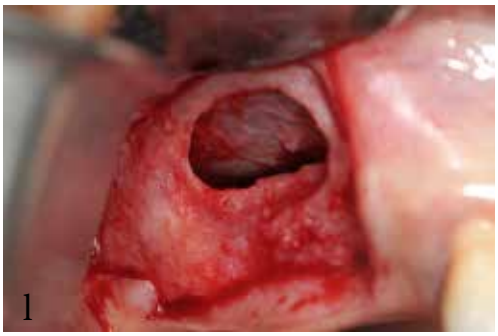
m The antral cavity will be grafted with cortical-cancellous allogenic bone mixed with PRP.

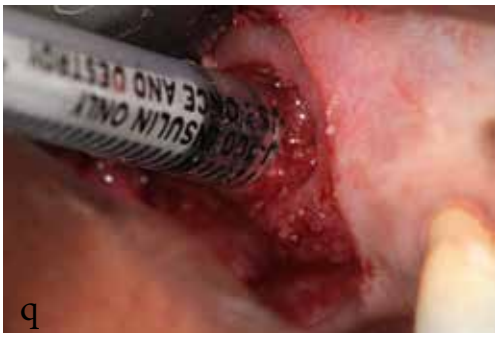
n The PRP Kit provides large membranes of a consistent thinkness and texture..

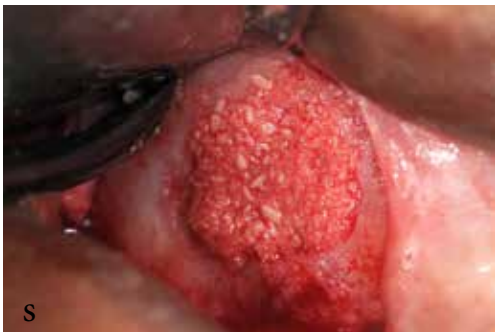
o Initial filling. The graft is delivered into the sinus cavity using an insulin syringe (I).

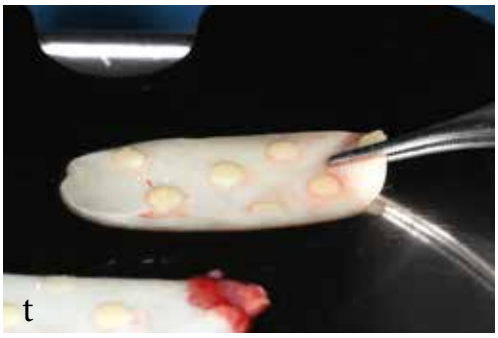
p Graft material is gently compacted in all directions with a bone packer.











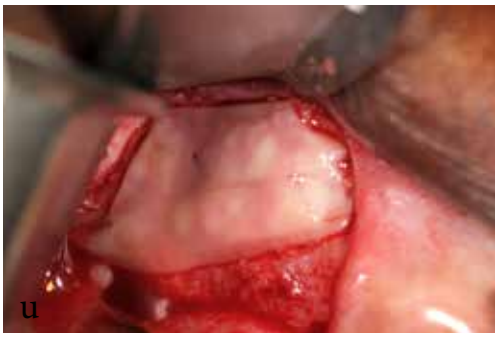


Fig. 5-14 (cont'd)

q More graft material is added in the central part of the sinus cavity.

r A large sinus curette is also used to gently spread the graft into the sinus cavity so that not empty voids are left.

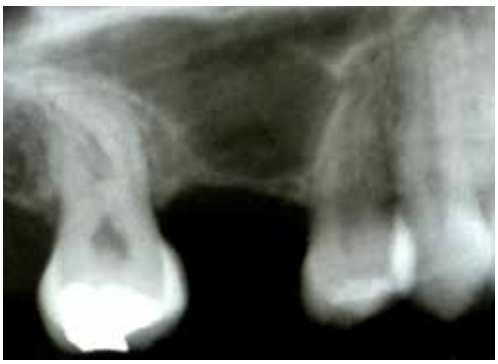
s Antral cavity fully filled.

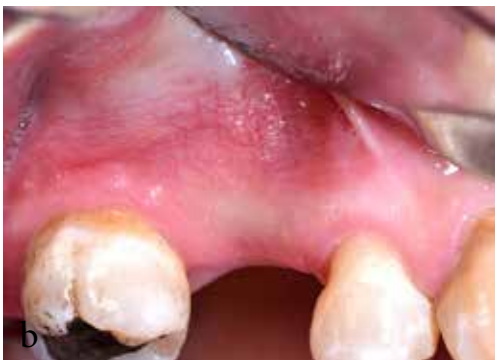
t PRP membranes ready for use.

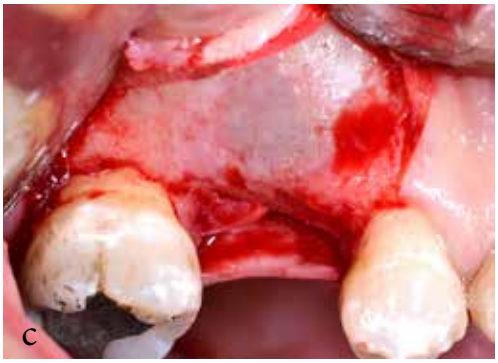
u Coverage of graft material with a PRP membrane.

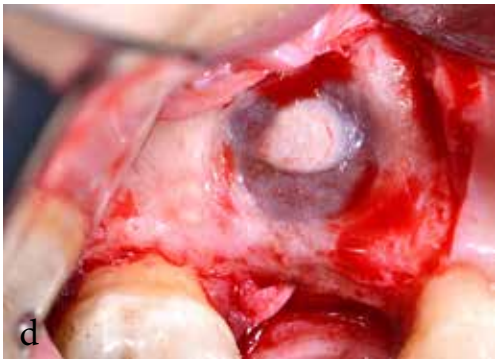
v Flap repositioned in place by single interrupted sutures.

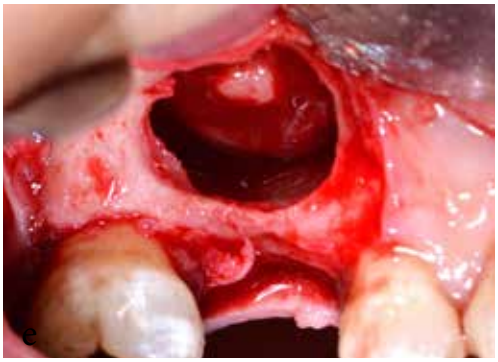
Notes

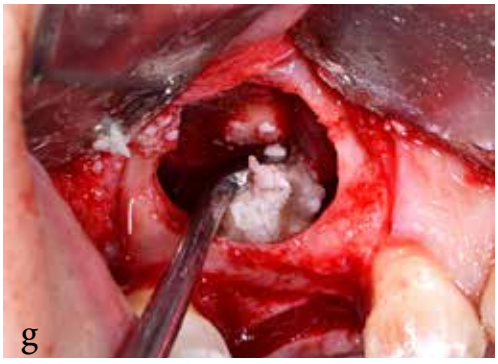












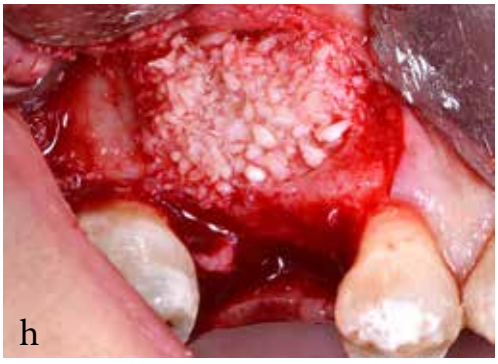


Fig. 5-15

a Radiographic pre-operative view.

b Clinical pre-operative view.

c Sinus cavity is evident after flap reflection.

d Initial osteotomy. Notice the vertical oval shape.

e Final osteotomy and membrane detachment.

f Bone is grafted into the antral cavity using a Molt curette.

g Graft material is gently compacted in all directions.

h Antral cavity fully filled with cortical allogenic bone graft.

Fig. 5-15 (cont'd)

i Coverage of graft material with a resorbable xenogenic collagen membrane.

j Radiographic post-operative view of grafted sinus immediately before implant placement.

k Clinical post-operative view of grafted sinus immediately before implant placement.

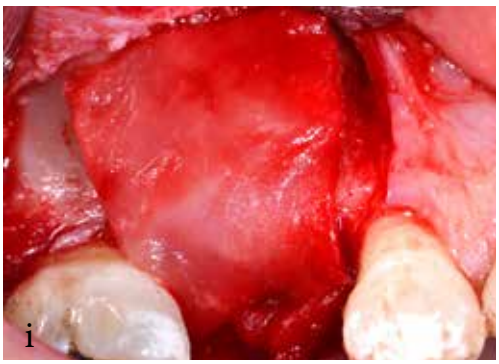
l After a slightly to the palate incision, the flap is released again.

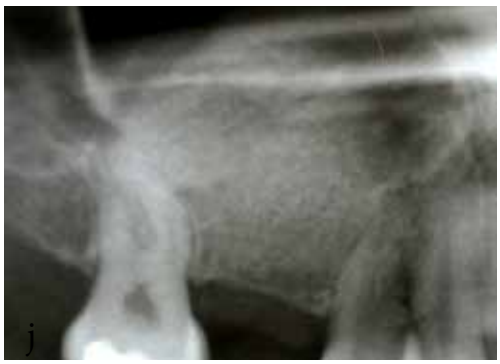
m Initial implant placement.

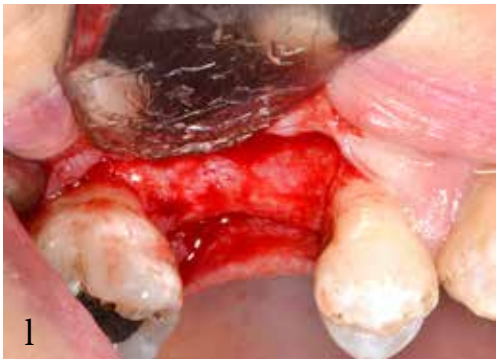
n Final position of implant.

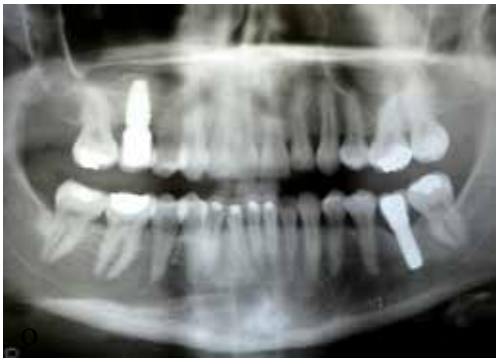
o Radiographic post-operative view after crown cementation.

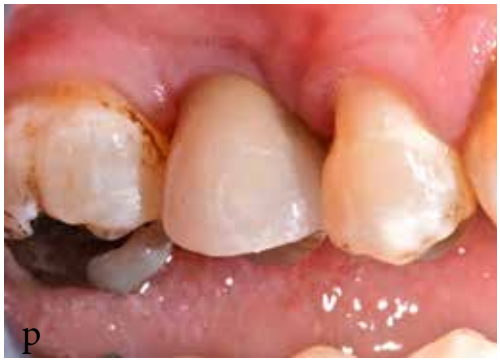
p One-year clinical post-operative follow-up view.











Notes

Fig. 5-16

a Radiographic pre-operative view.

b Radiographic close-up view of the area of the sinus to be grafted.

c Clinical pre-operative view.

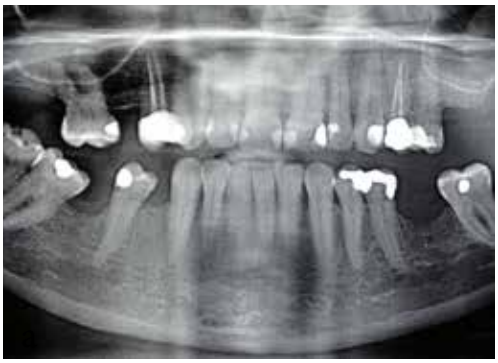
d Full-thickness flap refection. Translucency of sinus cavity is evident.

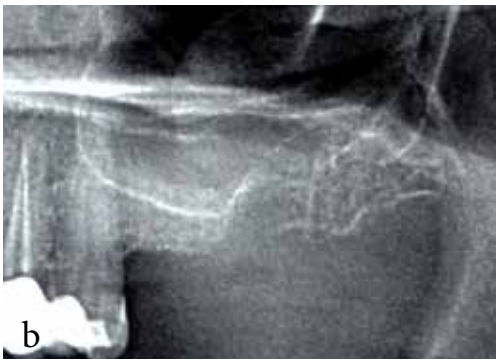
e Final osteotomy and initial membrane detachment.

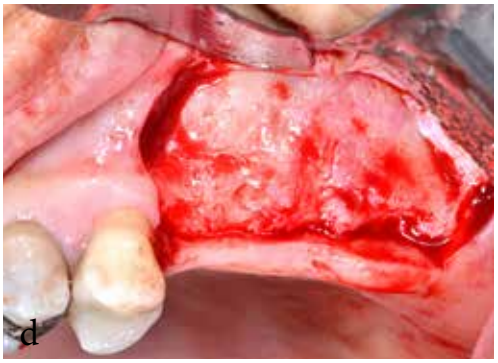
f Final detachment of the membrane after reaching the medial or internal bony wall of the sinus.

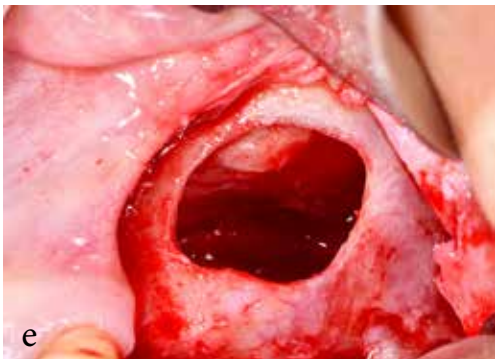
g Bone is delivered into the sinus cavity using an tuber-culin insulin syringe.

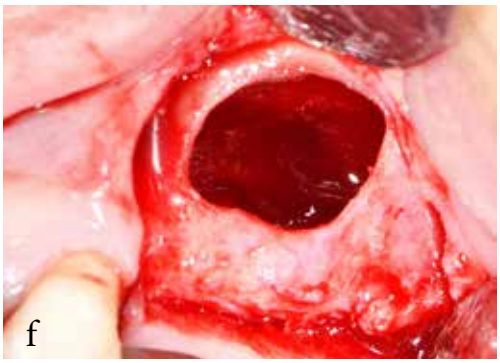
h The use of the syringe speeds up the placement of the graft material and thus the entire grafting process.

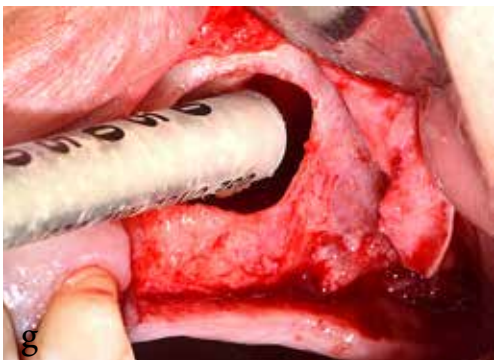


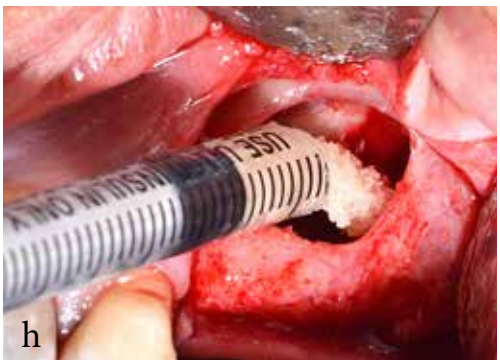


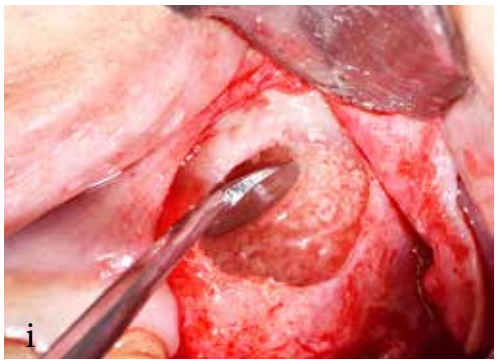


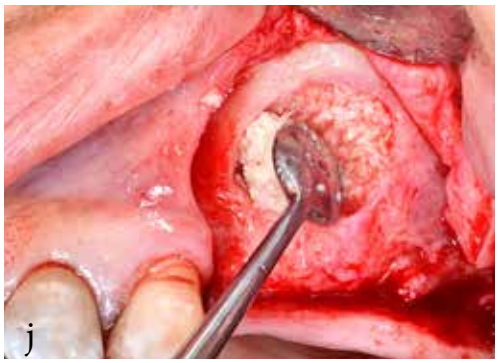


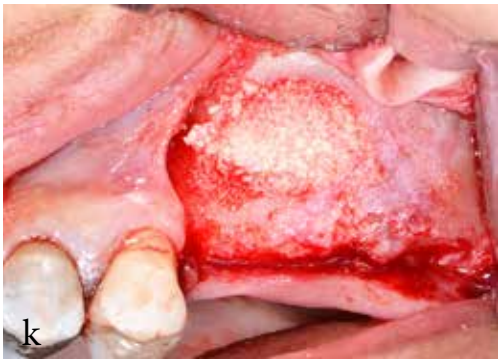


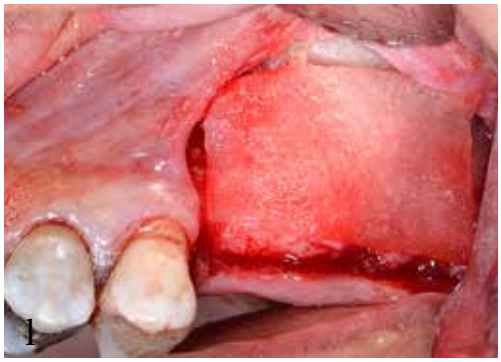


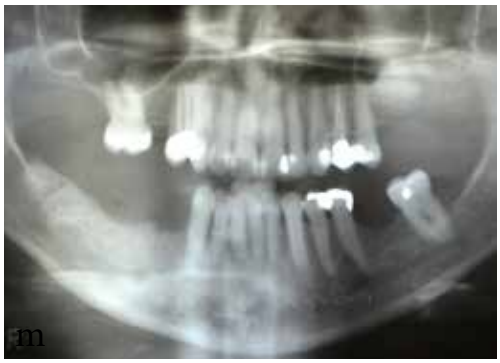


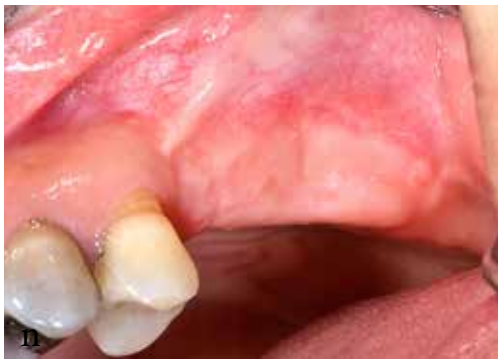












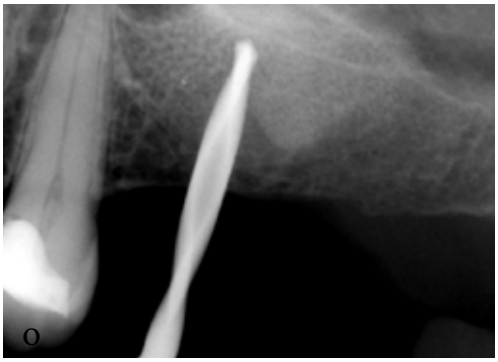


Fig. 5-16 (cont'd)

i Graft material is gently compacted in all directions.

j Final load of the graft using a Molt curette.

k Antral cavity fully filled with cortical allogenic bone graft.

l Coverage of graft material with a resorbable xenogenic collagen membrane.

m Radiographic post-operative view of grafted sinus immediately before implant placement.

n Clinical post-operative view of grafted sinus immediately before implant placement.

o Radiovisiography of pilot drill at implant osteotomy after a 6-month healing period.

p Initial implant placement.

Fig. 5-16 (cont'd)

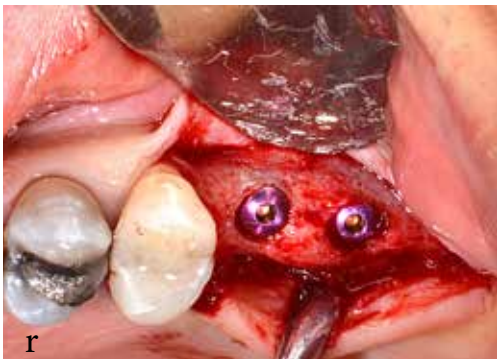
q Cheking parallelism of implants.

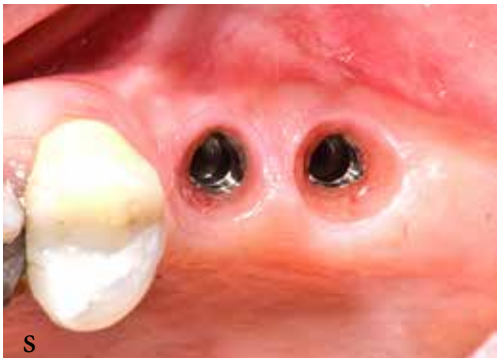
r Implants in place.

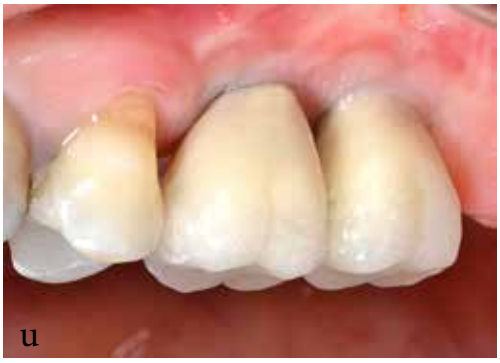
s Status of soft tissues around implants.

t Implant abutments before cementation of crowns.

u Crowns cemented in place.







Notes

Fig. 5-17

a Radiographic pre-operative view.

b Clinical pre-operative view of right side.

c Sinus cavity is evident after flap reflection.

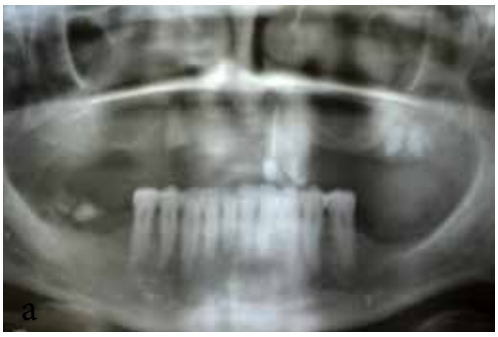
d Final detachment of the membrane.

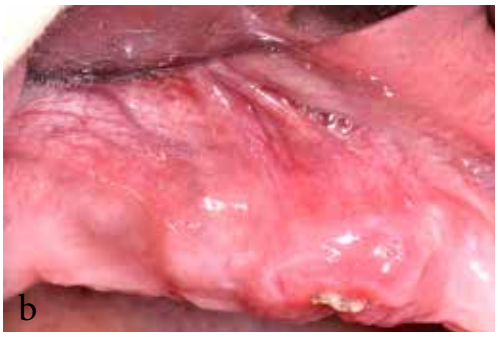
e Bone is delivered into the sinus cavity using a tuberculin syringe.

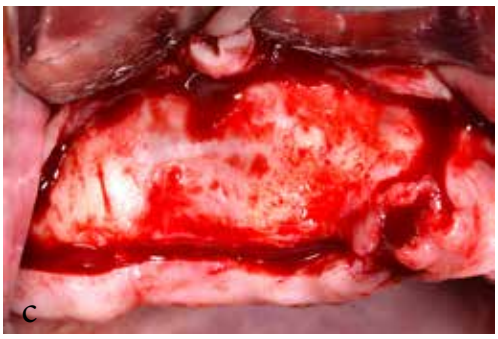
f Partial filling of the sinus cavity.

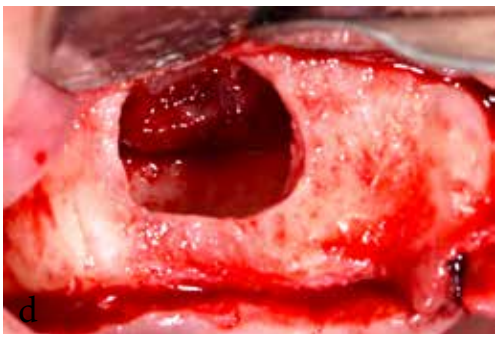
g A large sinus may require several syringes in order to be fully filled.

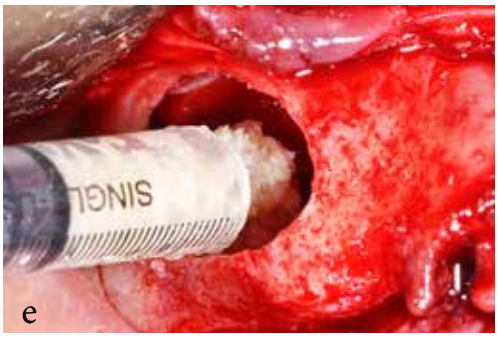
h Antral cavity fully filled with cortical allogenic bone graft.

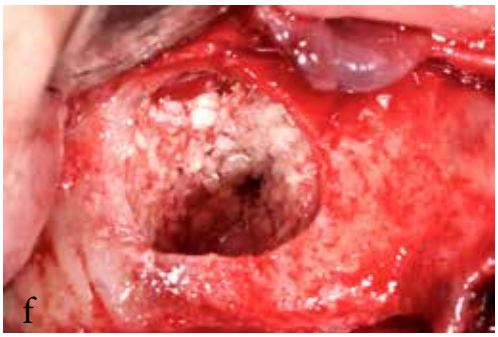


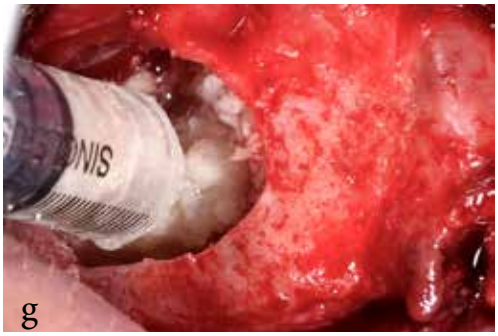


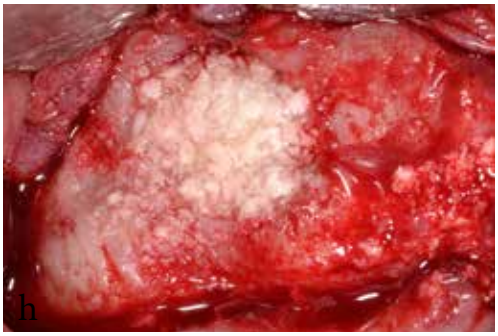


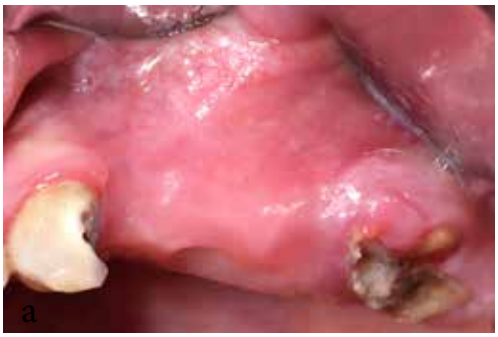


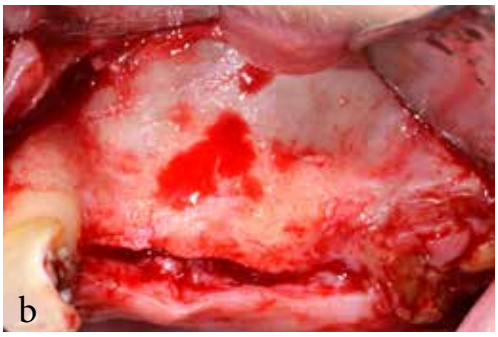


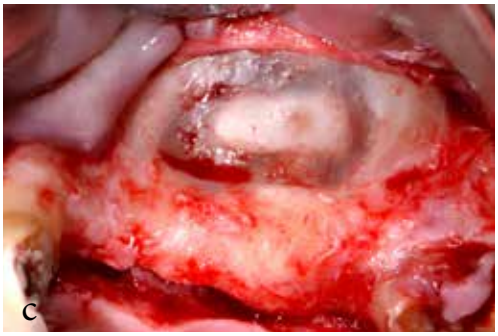


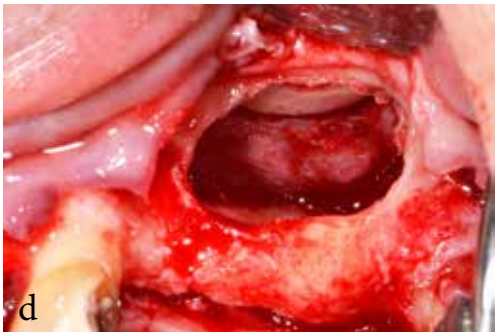


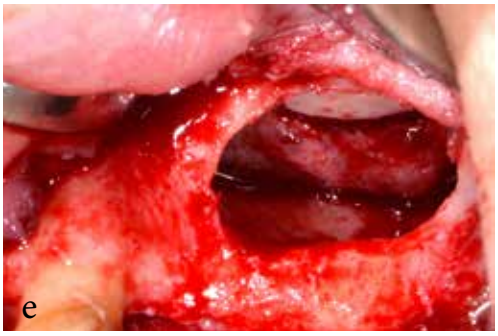


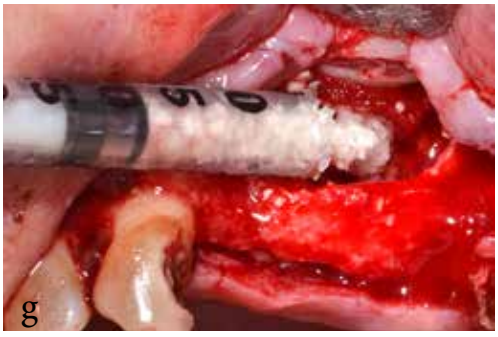


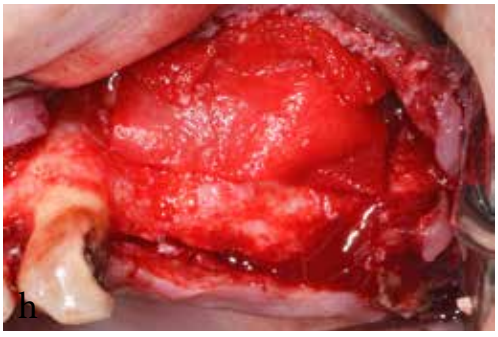












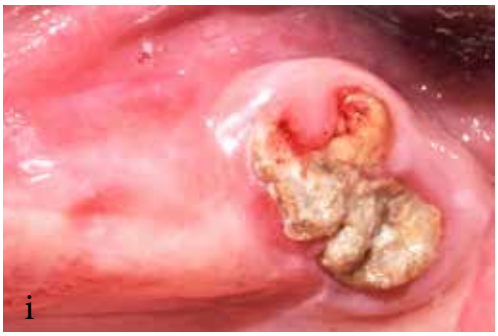


Fig. 5-17 (cont'd)

a Clinical pre-operative view of left side.

b Sinus cavity is evident after flap reflection.

c Initial osteotomy. Notice the horizontal oval shape.

d Initial detachment of the membrane.

e Final detachment of the membrane.

f Bone is delivered into the sinus cavity using a tuberculin syringe.

g Syringe after syringe of bone, the sinus cavity is completely filled.

h Coverage of graft material with a resorbable xenogenic collagen membrane.

i Clinical view of root tips of tooth #17.

j Root tips are extracted.

Fig. 5-17 (cont'd)

k Sockets are grafted with cortical allogenic bone.

l The graft is covered with a d-PTFE membrane.

m Some sutures stabilize the membrane in place.

n Clinical view of tooth # 10 and # 11.

o Teeth are extracted for socket preservation.

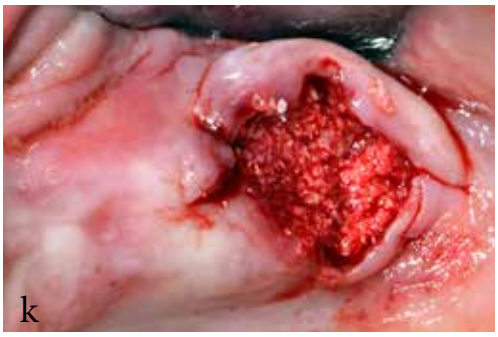
p Sockets are grafted with cortical allogenic bone.

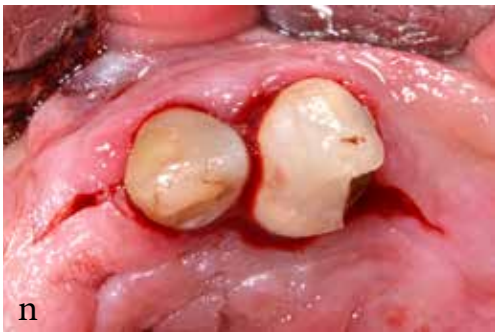
q The graft is covered with a d-PTFE membrane.

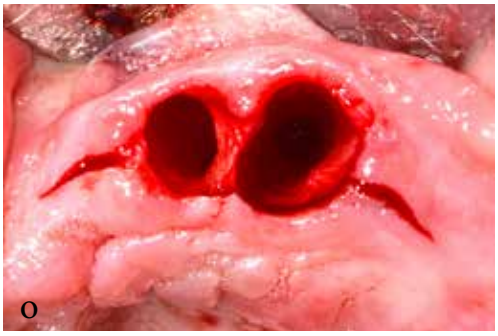
r Some sutures stabilize the membrane in place.

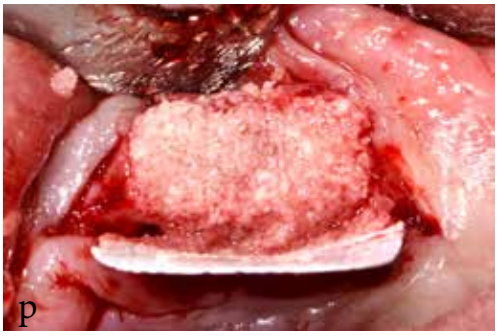
s Clinical view of membrane on socket of teeth # 10 and # 11 immediately before removal.

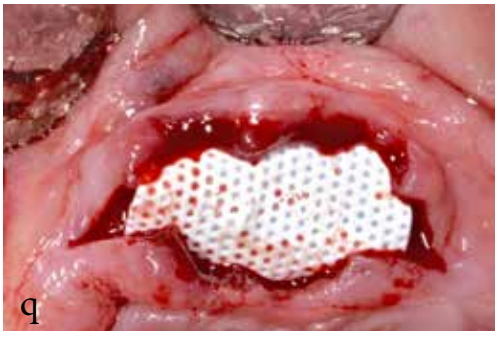
t Mature connective tissue has formed under it after a 4-week healing period.

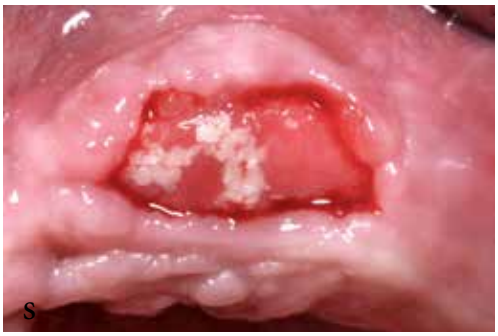


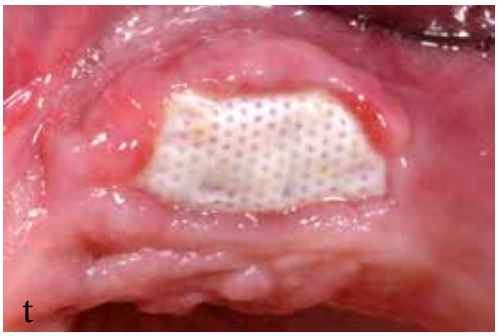


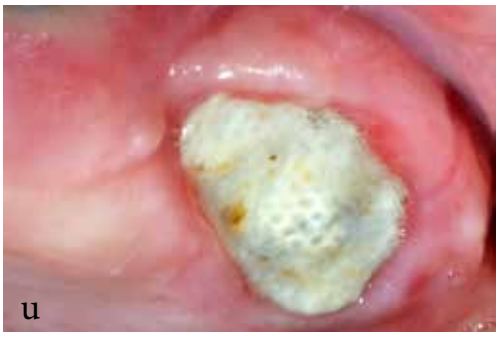


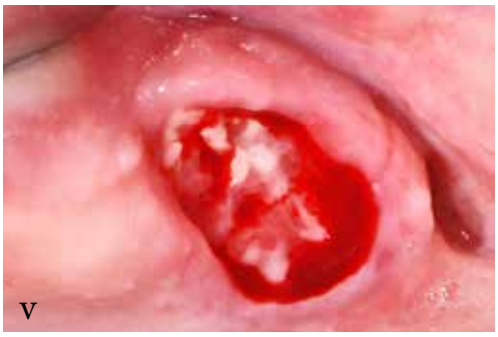


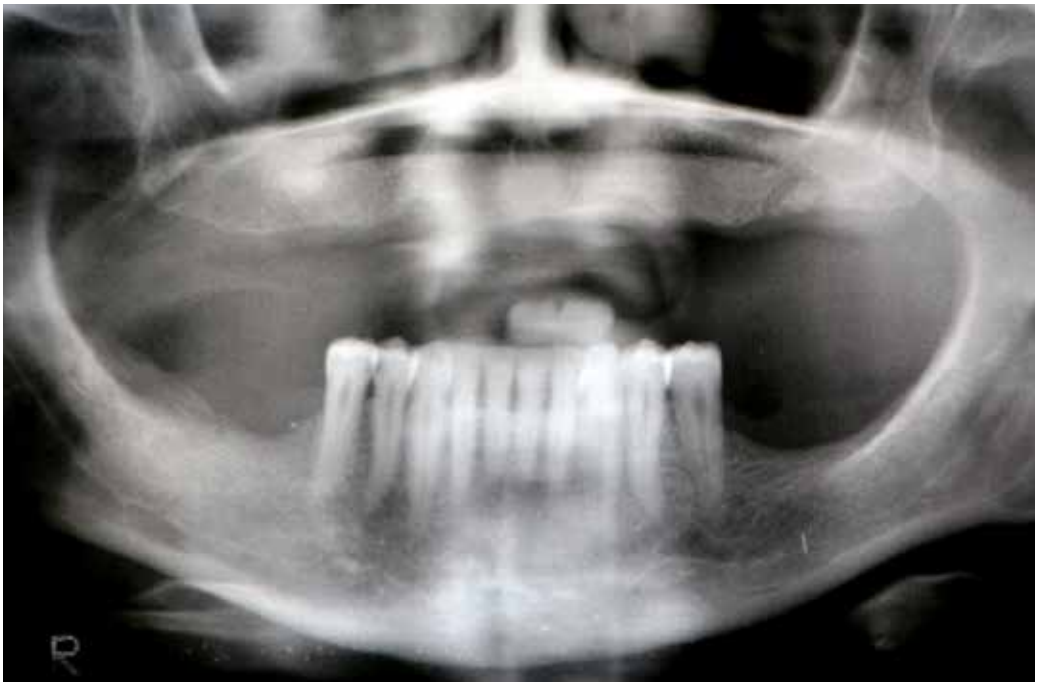


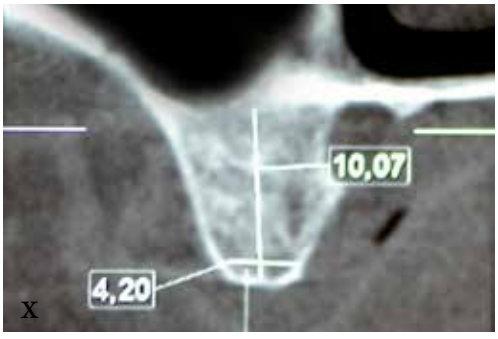


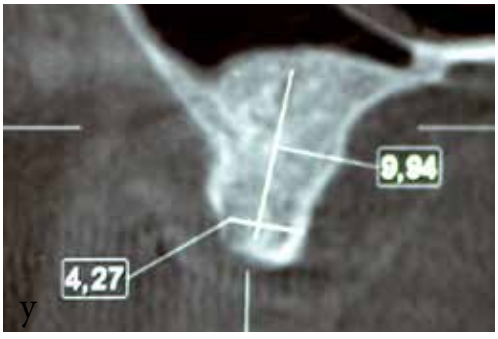


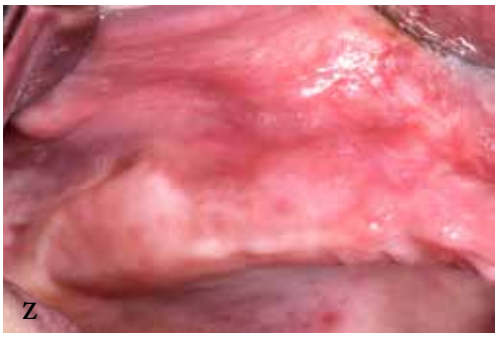












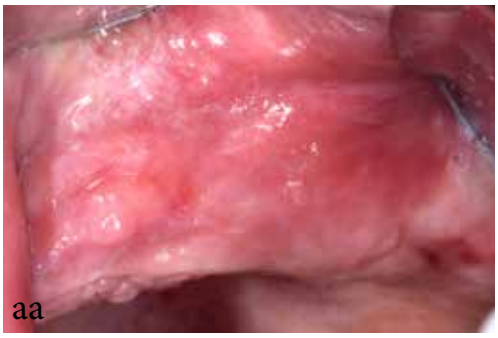


Fig. 5-17 (cont'd)

u Clinical view of membrane on socket of tooth # 17 immediately before removal.

v Mature connective tissue has formed under it after a 4-week healing period.

w Radiographic post-operative view of grafted sinuses and sockets immediately before implant placement.

x CBT slice of grafted sinus(I).

y CBT slice of grafted sinus(II).

z Clinical post-operative view. Right side.

aa Clinical post-operative view. Left side.

Fig. 5-17 (cont'd)

ab Implants in place. Right side.

ac Implants in place. Left side.

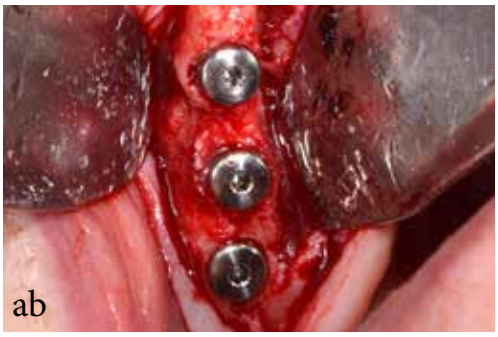
ad Status of soft tissues around implants immediately before taking the final impression.

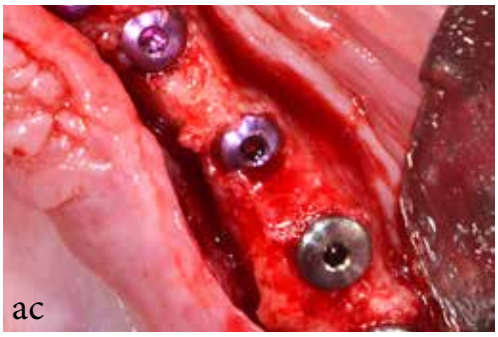
ae Occlusal view of the final screw-retained full-arch restoration.

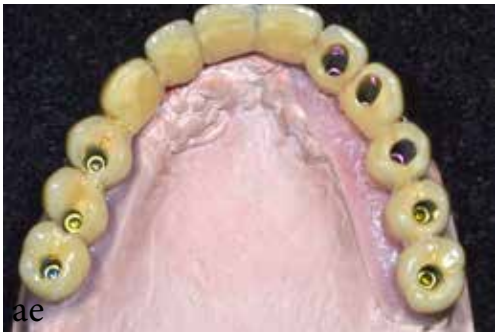
af Occlusal view of the restoration in place.

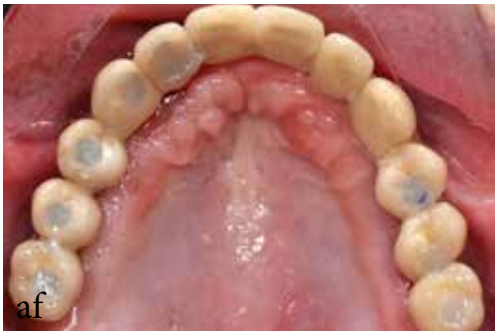
ag Achieved final result.

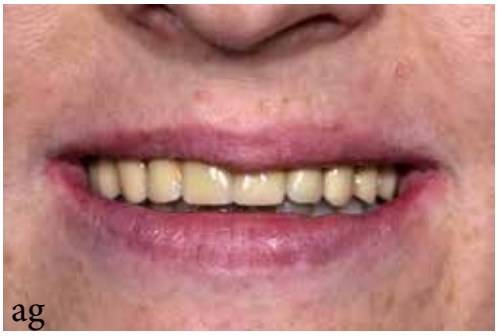
ah One-year radiographic postoperative follow-up view.

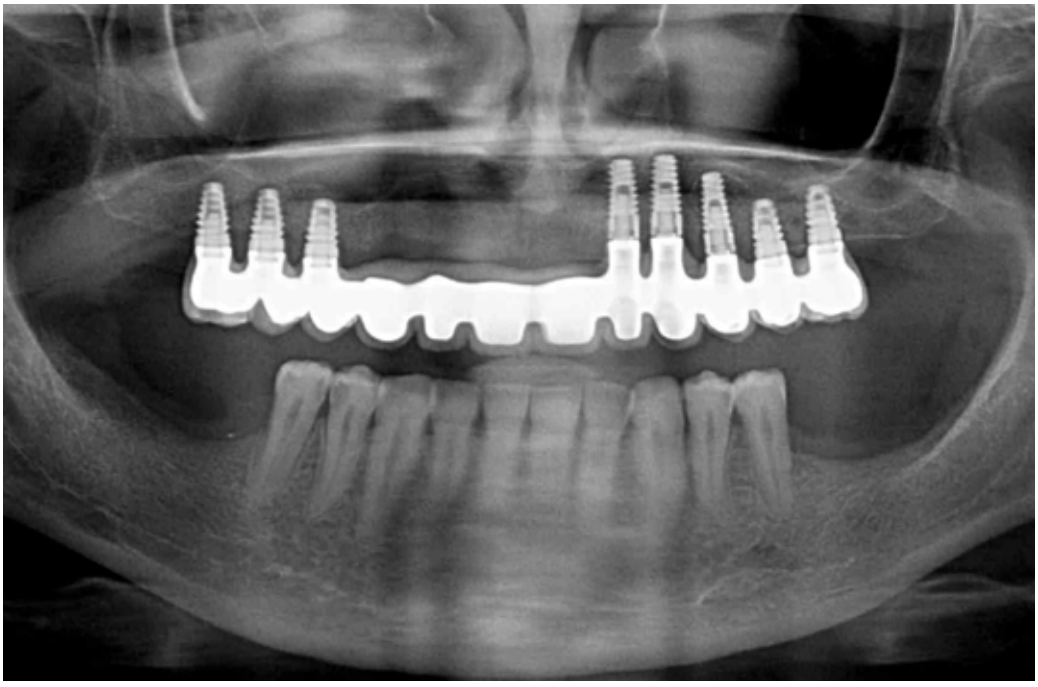












Notes

Fig. 5-18

a Radiographic close-up view of left sinus.

b Radiographic close-up view of right sinus.

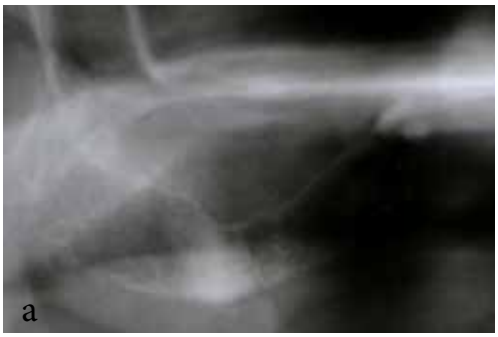
c Radiographic pre-operative view.

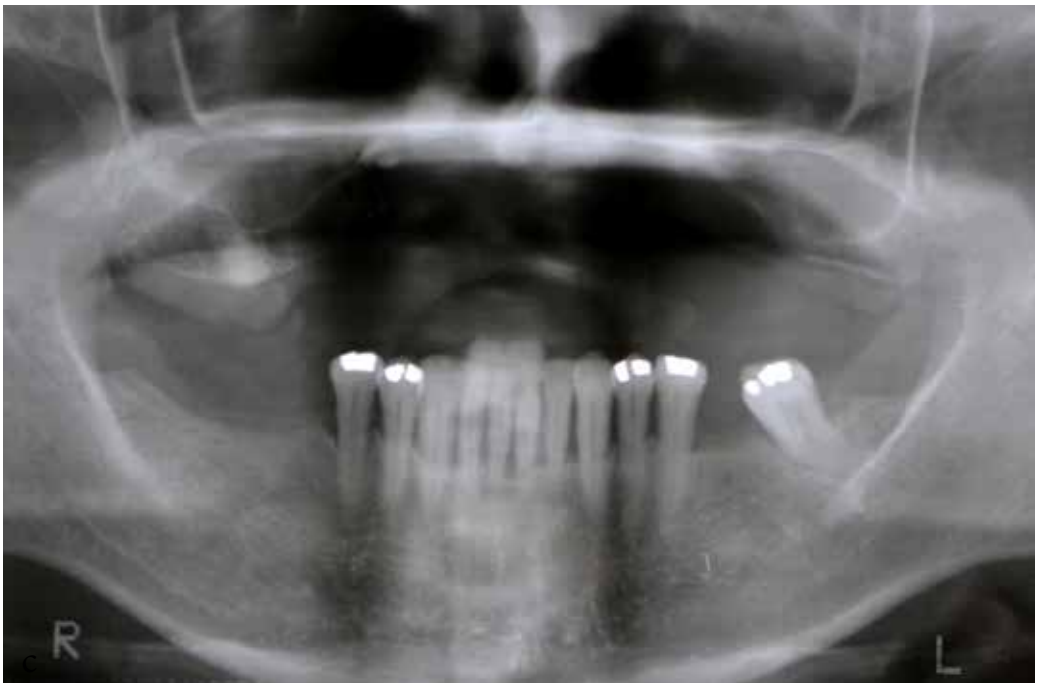
d Clinical pre-operative view of left side.

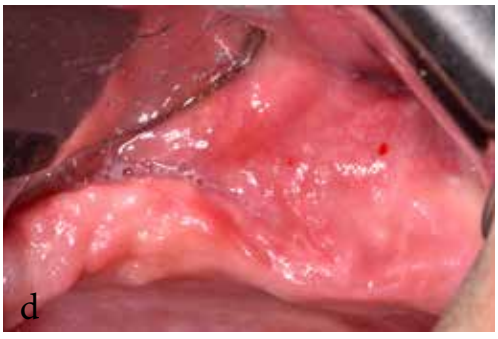
e Sinus cavity is evident after flap reflection.

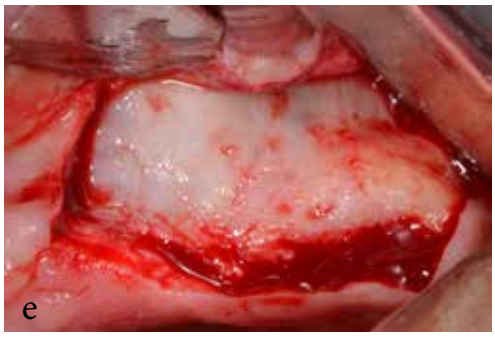
f Large horizontal oval shape osteotomy view.

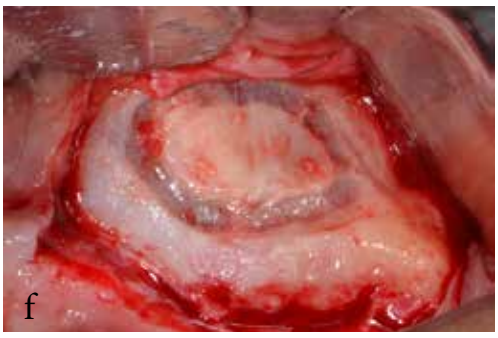
g Membrane detachment completed.

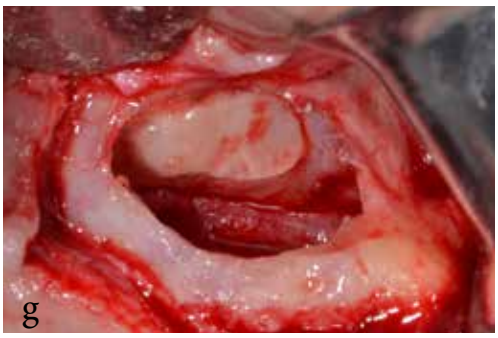


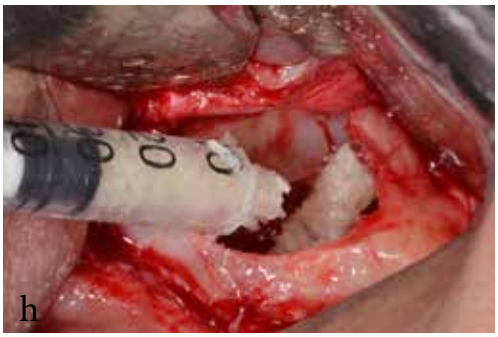


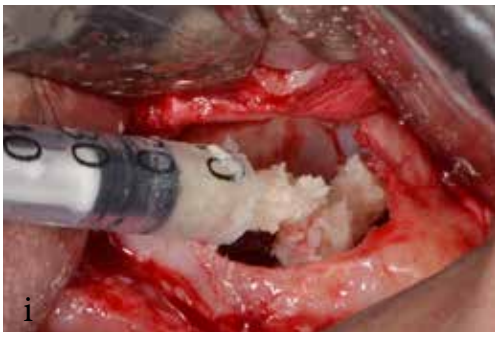


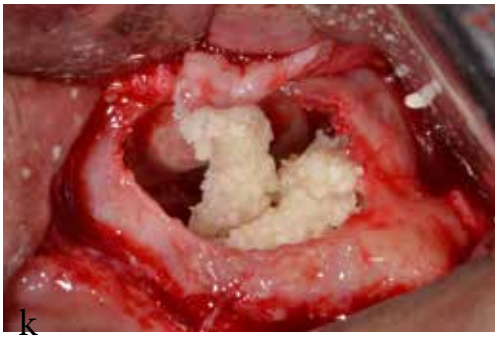


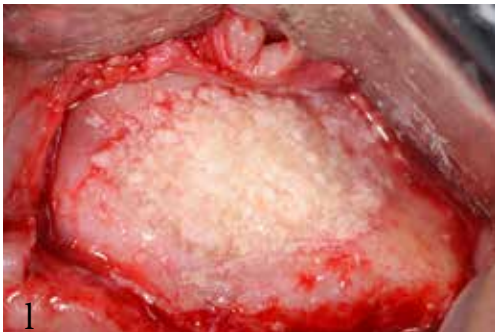


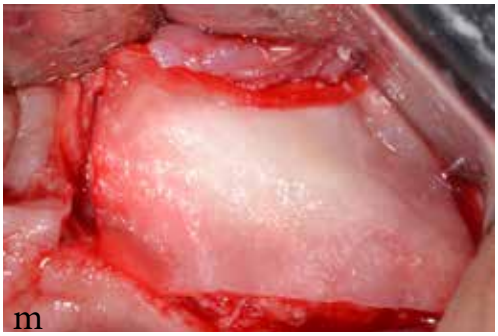


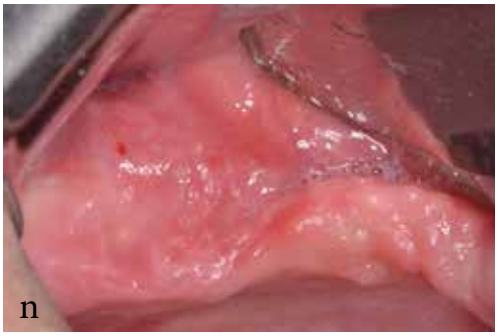












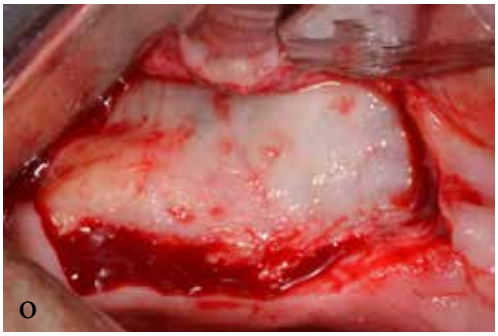


Fig. 5-18 (cont'd)

h Bone is delivered into the sinus cavity using an tuberculin syringe.

i Delivery of graft in the distal part of the sinus cavity.

j A large sinus may require several syringes in order to be fully filled.

k Delivery of graft in the central part of the sinus cavity.

l Antral cavity fully filled with cortical-cancellous allogenic bone graft.

m Coverage of graft material with a resorbable xenogenic collagen membrane.

n Clinical pre-operative view of patient's right side.

o Sinus cavity is evident after flap reflection.

Fig. 5-18 (cont'd)

p Large horizontal oval shape osteotomy view.

q Membrane detachment completed.

r Bone is delivered into the sinus cavity using a tuberculin syringe.

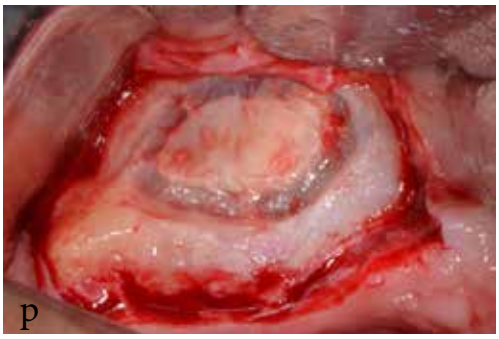
s Delivery of graft in the distal part of the sinus cavity.

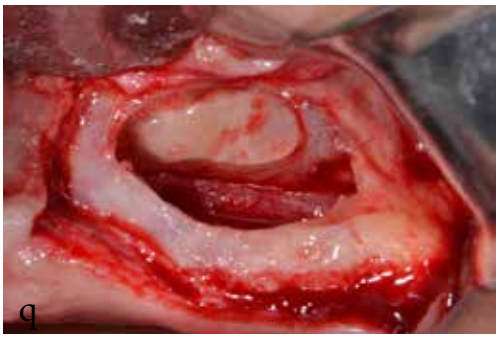
t Antral cavity fully filled with cortical-cancellous allogenic bone graft.

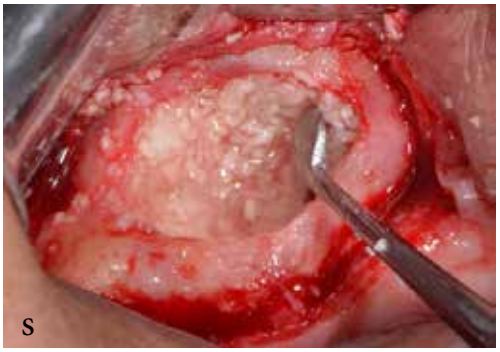
u Radiographic post-operative view of grafted sinuses after six months of healing and immediately before implant placement.

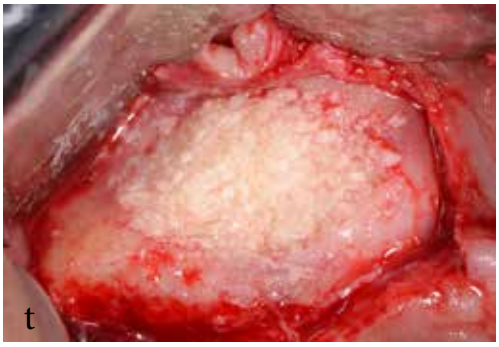
v Right flap reflection immediately before implant placement.

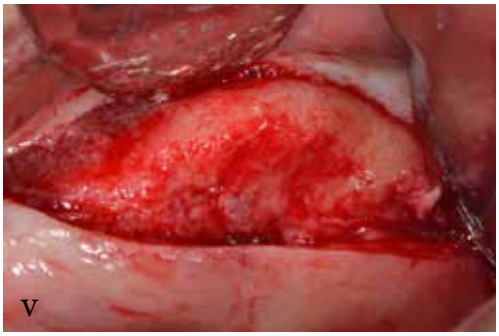
w Implants in place. Notice the complete healing of the sinus window with bone.

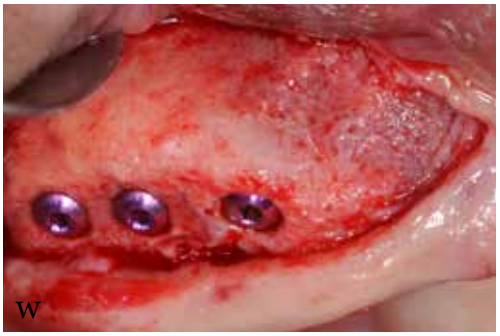


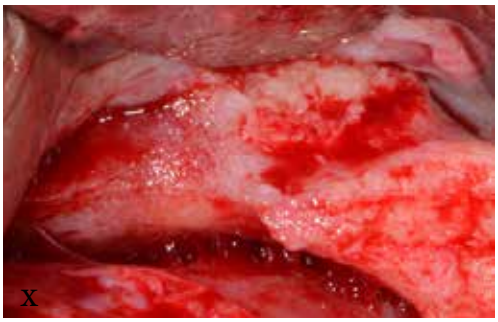


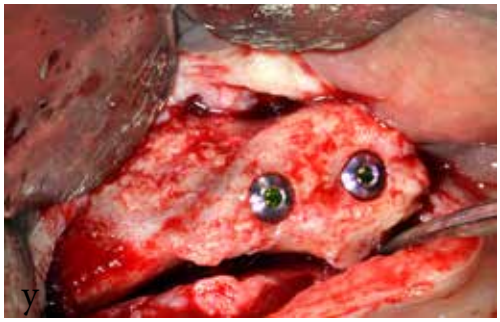


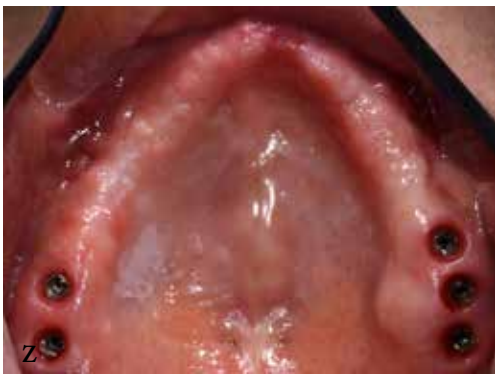


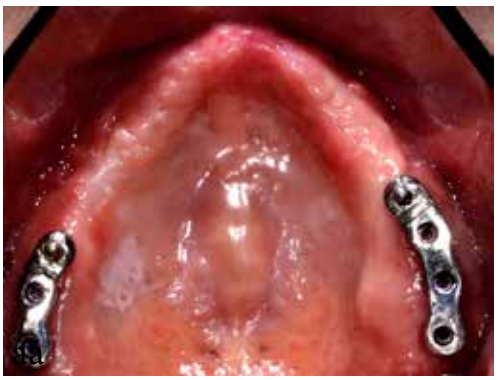


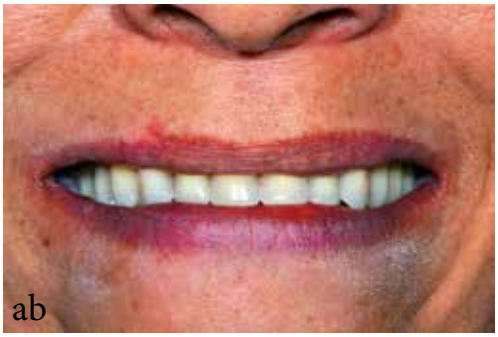












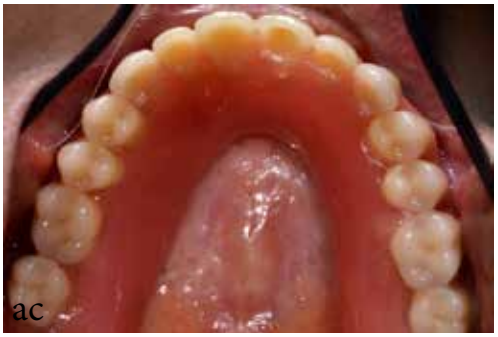


Fig. 5-18 (cont'd)

x Left flap reflection immediately before implant placement.

y Implants in place. Notice the complete healing of the sinus window with bone.

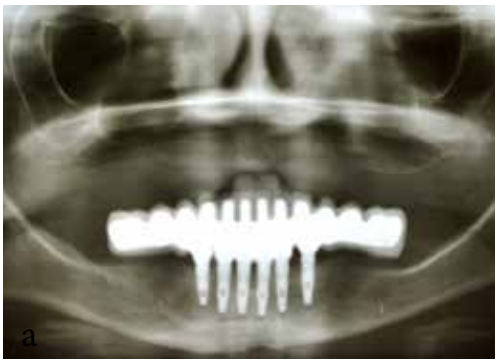
z Status of soft tissues around implants immediately before taking the final impression.

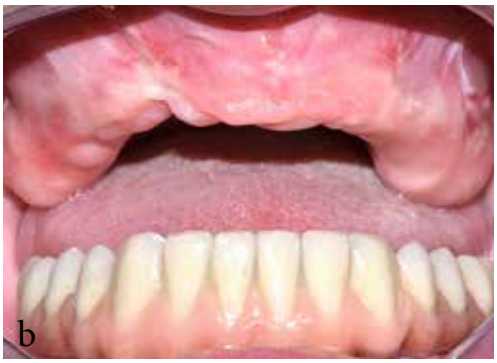
aa Occlusal view of two cast bars.

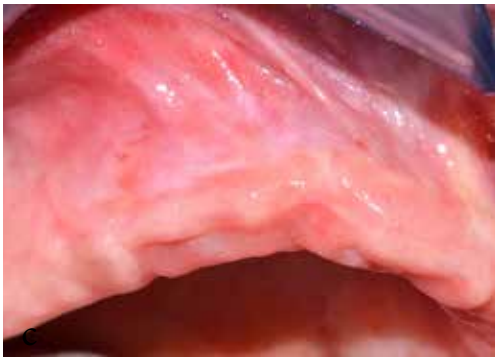
ab Achieved final result.

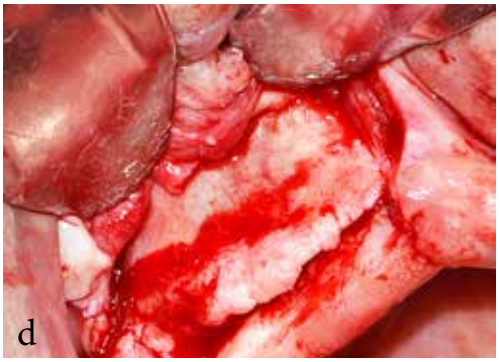
ac Occlusal view of the restoration in place.

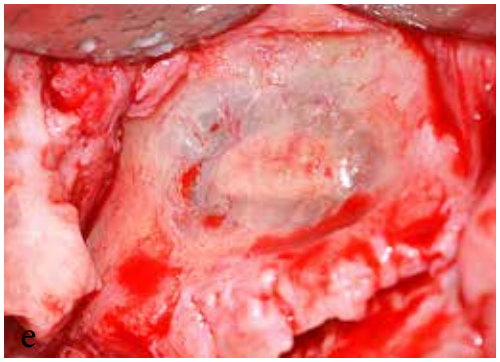
Notes

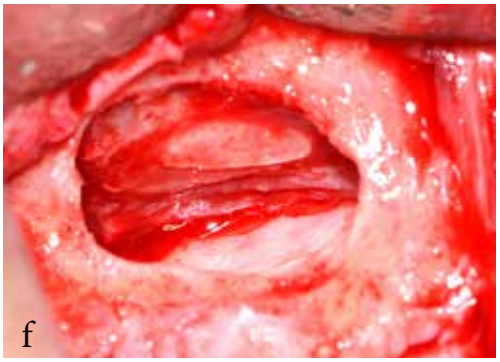


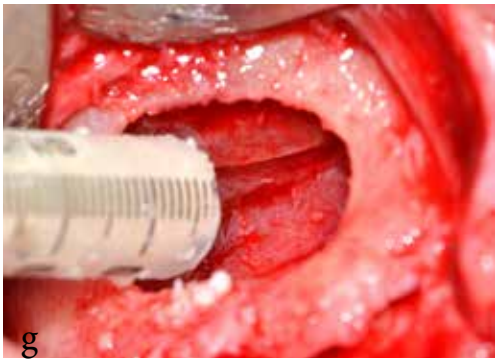












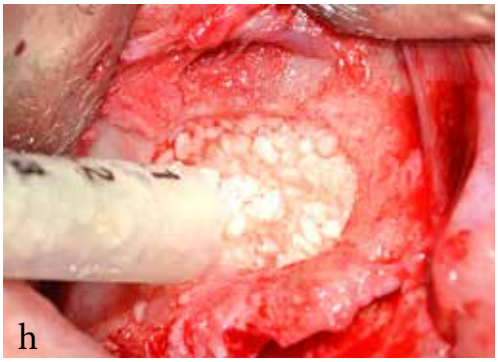


Fig. 5-19

a Radiographic pre-operative view.

b Clinical pre-operative view of upper maxilla.

c Clinical pre-operative view of right side.

d Sinus cavity is evident after flap reflection.

e Initial osteotomy. Notice the horizonal oval shape.

f Enlarged osteotomy and final detachment of the membrane.

g Bone is delivered into the sinus cavity using a tuberculin syringe.

h Partial filling of the sinus cavity.

Fig. 5-19 (cont'd)

i Antral cavity fully filled with cortical allogenic bone graft.

j Coverage of graft material with a resorbable xenogenic collagen membrane.

k Clinical pre-operative view of left side.

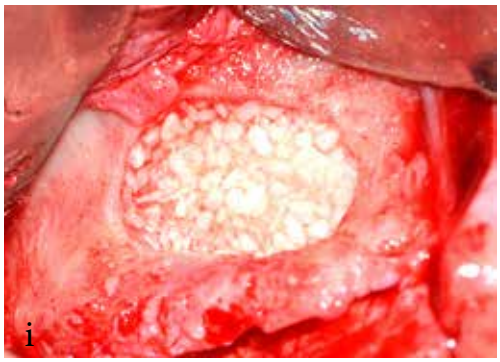
l Sinus cavity is evident after flap reflection.

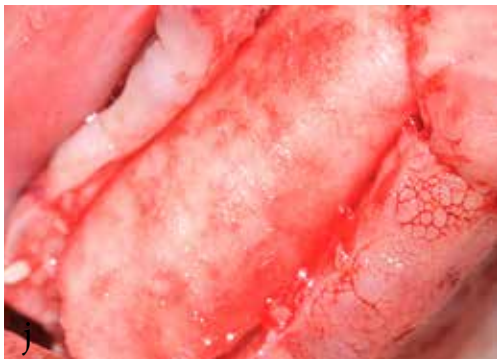
m Final horizontal oval shape osteotomy and final detachment of the membrane.

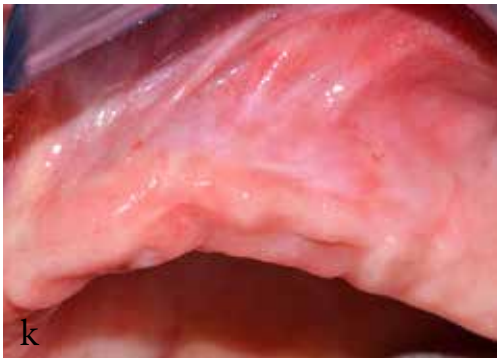
n Bone is delivered into the sinus cavity using a tuberculin syringe.

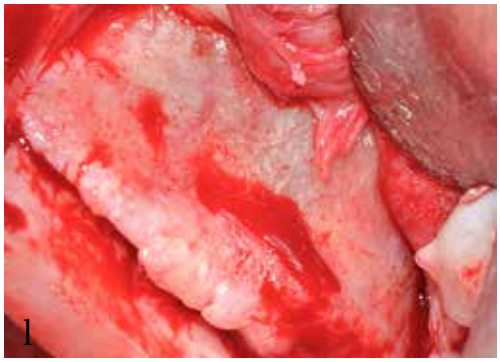
o Antral cavity fully filled with cortical allogenic bone graft.

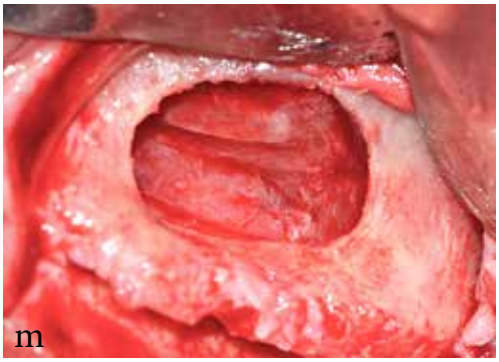
p Coverage of graft material with a resorbable xenogenic collagen membrane.

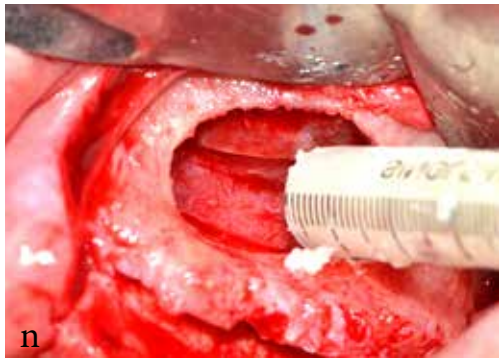


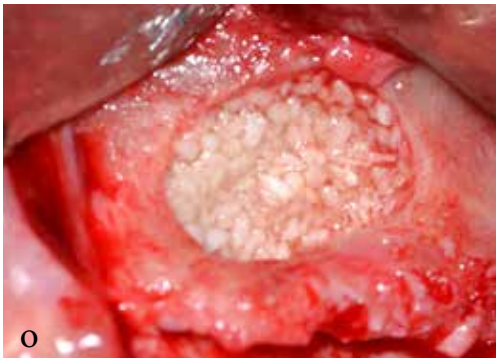


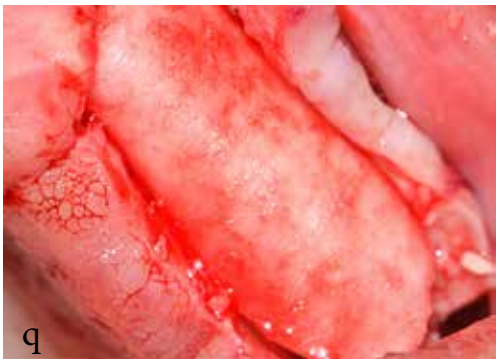


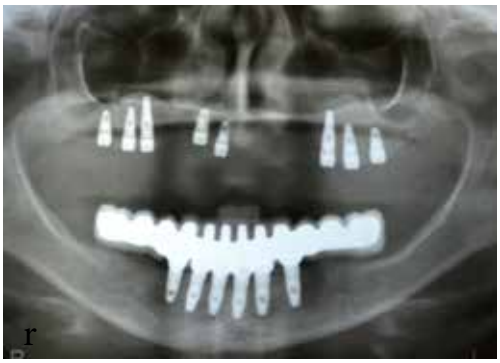


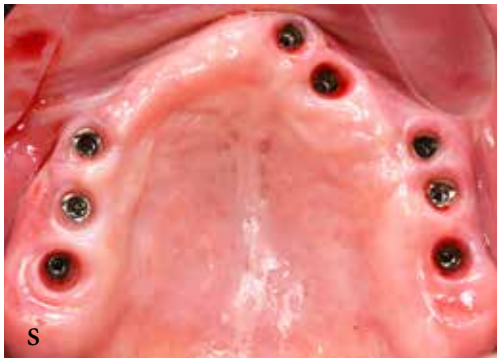


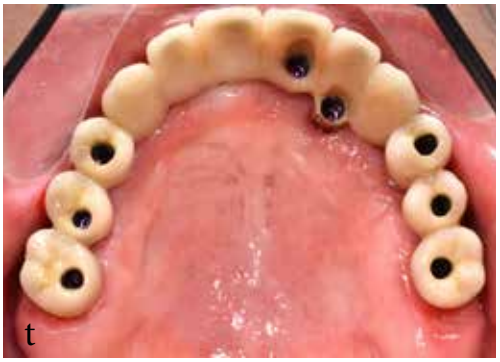












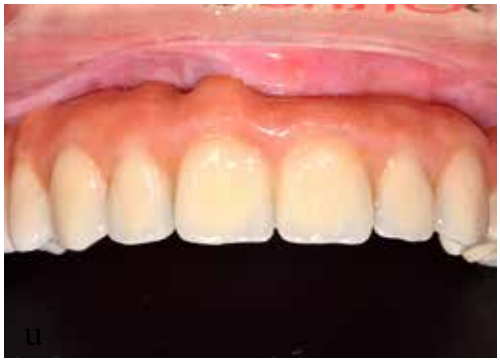


Fig. 5-19 (cont'd)

q Radiographic post-operative view of oseointegrated implants immediately after healing abutment connections.

r Status of soft tissues around implants immediately before taking the final impression.

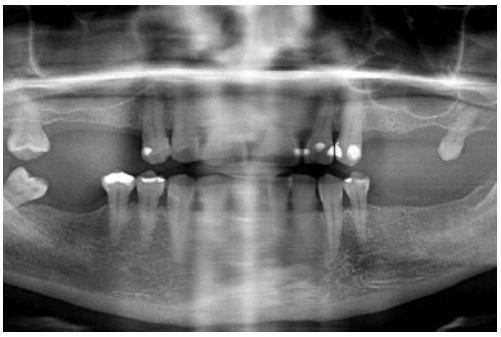
s Occlusal view of the final screw-retained full-arch restoration.

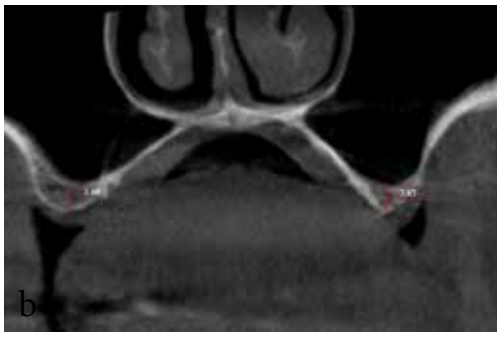
t Buccal view of the final screw-retained full-arch restoration.

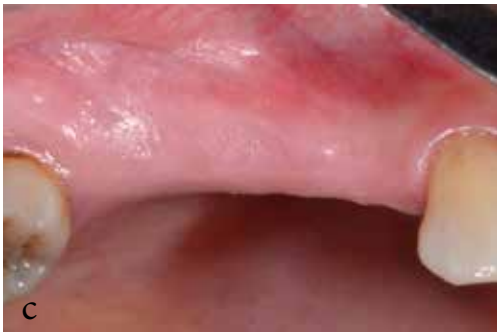
u Achieved final result.

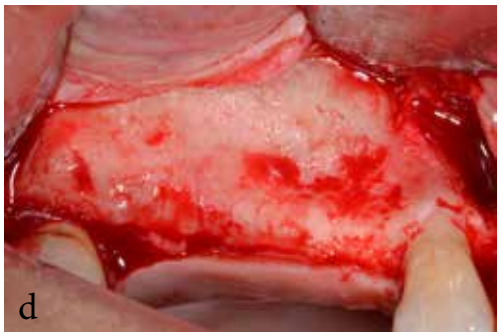
v One-year radiographic post-operative follow-up view.

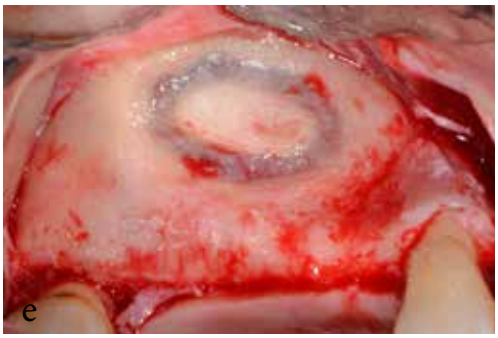
Notes

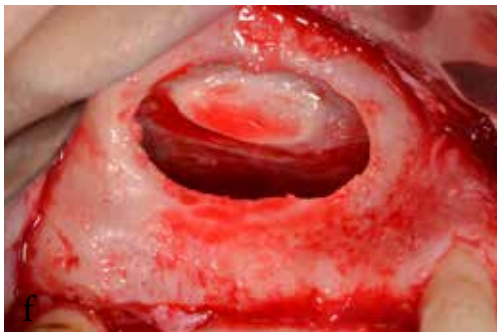


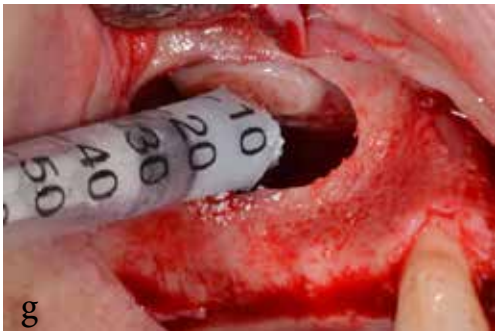












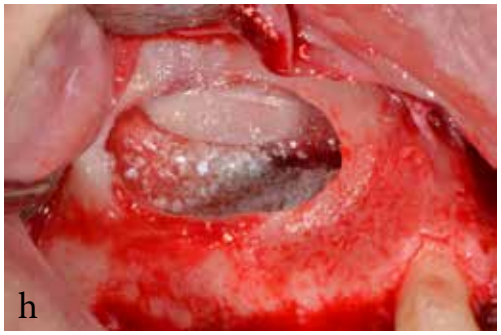


Fig. 5-20

a Radiographic pre-operative view.

b CBT slice pre-operative view of right sinus.

c Clinical pre-operative view.

d Full-thickness flap refection.

e Final osteotomy. Notive the vertical oval shape.

f Sinus membrane detachment completed.

g An aloplastic graft material is delivered into the sinus cavity using an insulin syringe.

h Initial filling of the sinus cavity.

Fig. 5-20 (cont'd)

i More graft is added to the cavity using a Molt curette.

j Antral cavity fully filled.

k Coverage of graft material with a resorbable xenogenic collagen membrane.

l Radiographic post-operative view of grafted sinus immediately before implant placement.

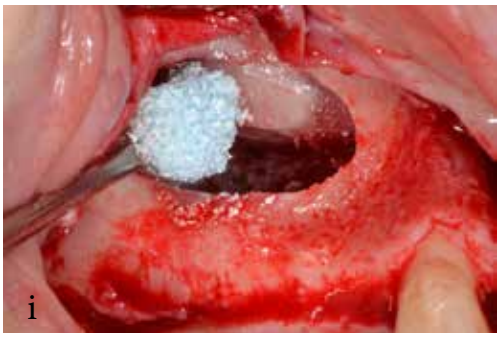
m Implants osteotomies completed.

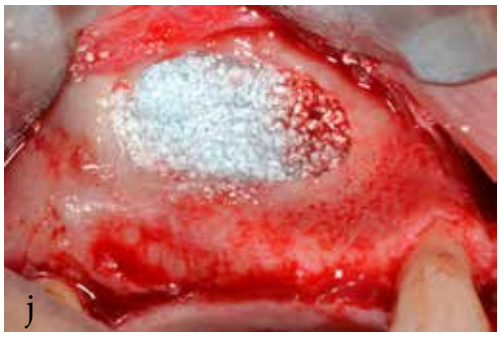
n Implants in place.

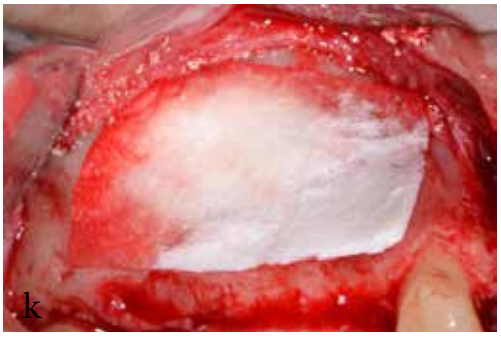
o Radiographic post-operative view of oseointegrated implants immediately before healing abutment connections.

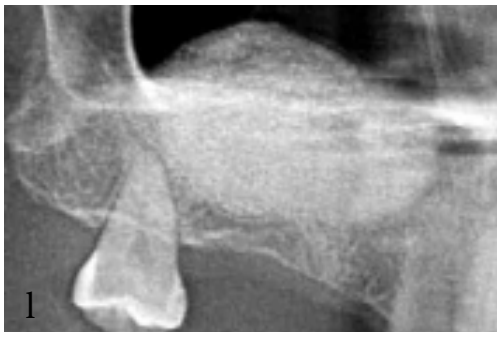
p Status of soft tissues around implants immediately before taking the final impression.

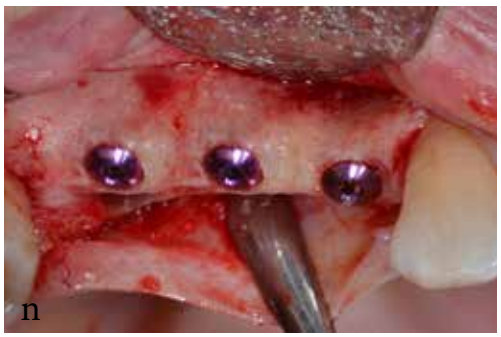
q Bridge cemented in place.

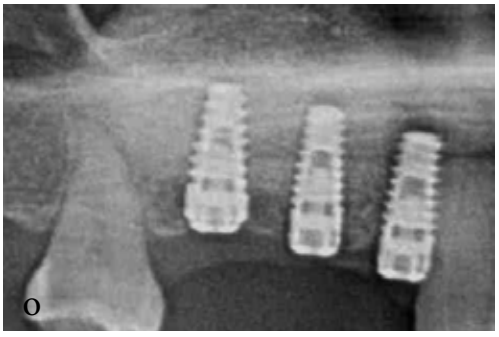


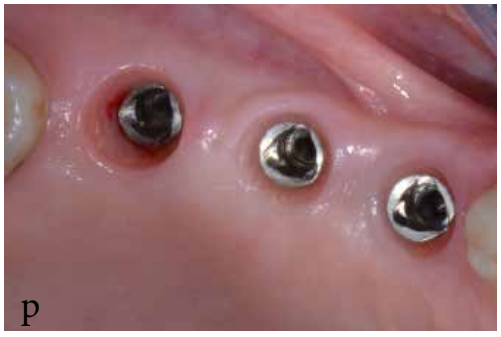


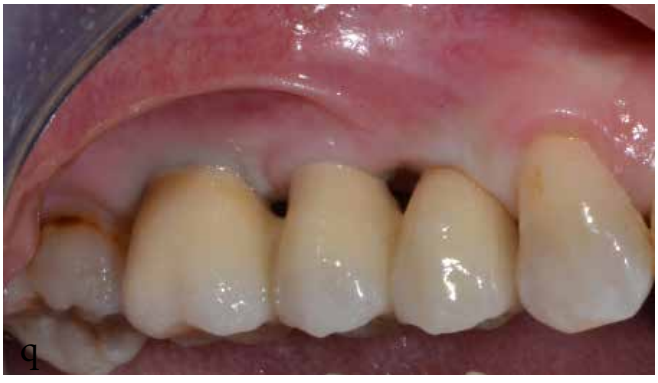












Notes

Fig. 5-21

Lateral Wall Sinus Lift with the SCA Kit

a Radiographic pre-operative view.

b Phlebotomy to obtain patient's own blood (I).

c Phlebotomy to obtain patient's own blood (II).

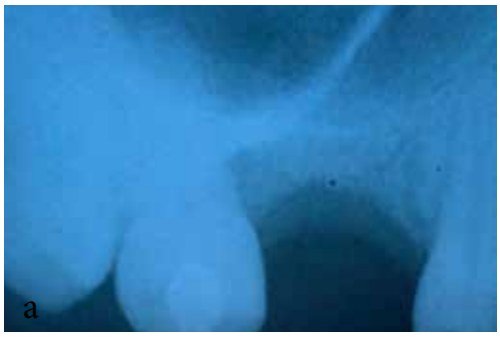
d Phlebotomy to obtain patient's own blood (III).

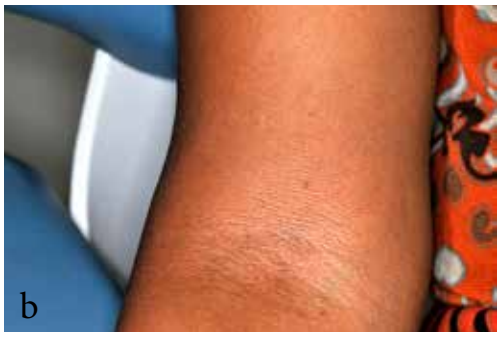
e Phlebotomy to obtain patient's own blood (VI).

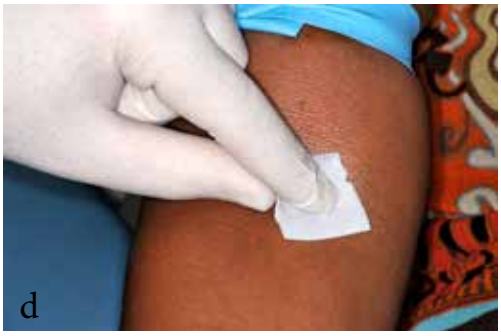
f Clinical pre-operative view.

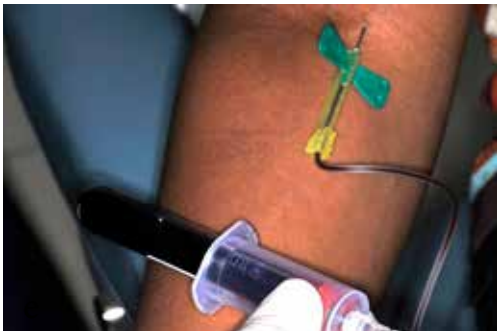
g Full-thickness flap refection.

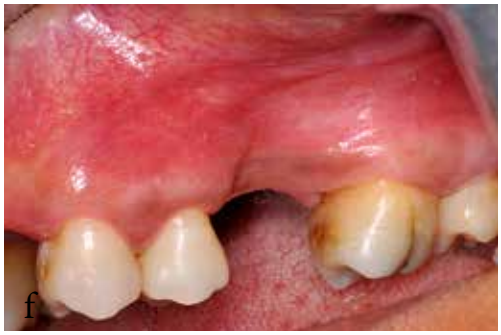
h The bur is designed to trim the bone only, leaving the membrane intact, which is proven using it against the surgeon's gloves.

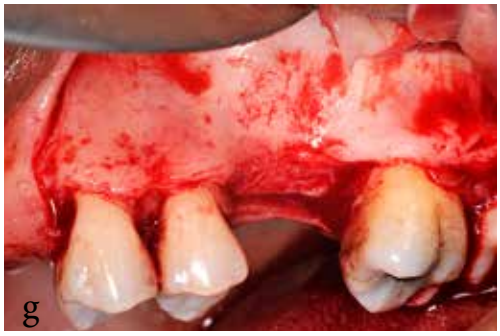


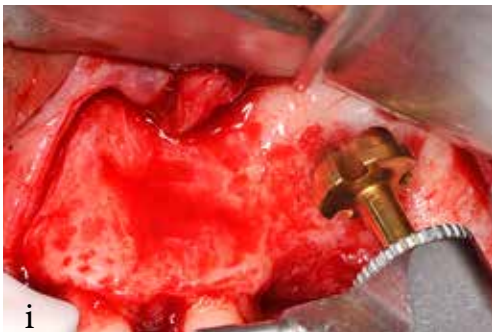


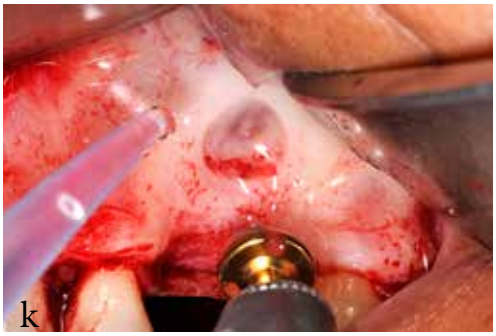


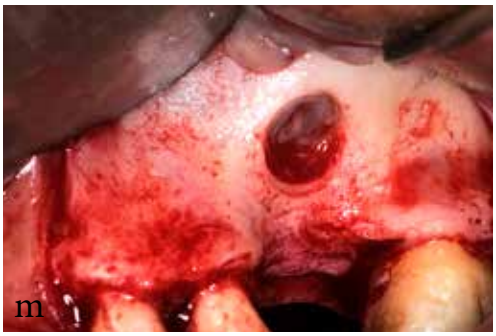












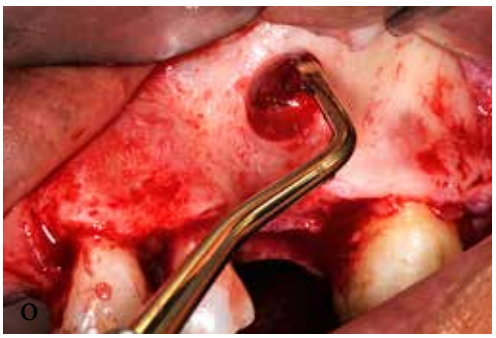


Fig. 5-21 (cont'd)

i The osteotomy consists in using the specifically designed bur to progressively remove the buccal cortical plate (I).

j The osteotomy consists in using the specifically designed bur to progressively remove the buccal cortical plate (II).

k The osteotomy consists in using the specifically designed bur to progressively remove the buccal cortical plate (III).

l The osteotomy consists in using the specifically designed bur to progressively remove the buccal cortical plate (VI).

m The process continues until the translucency of the sinus membrane is evident.

n Initial detachment of the membrane from the sinus floor.

o Initial detachment of the membrane from the distal side.

p Initial detachment of the membrane from the mesial side.

Fig. 5-21 (cont'd)

q Initial detachment of the membrane from the upper side.

r Final detachment of the membrane.

s Obtention of a PRP membrane from a lab tube by centrifugation of patient's own blood.

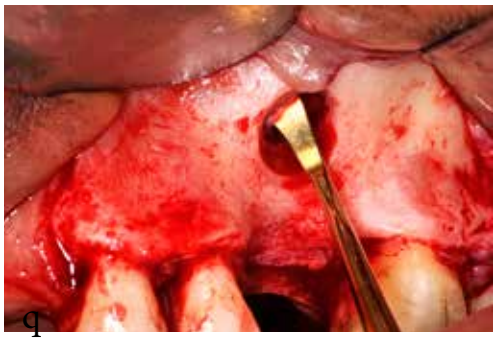
t The PRP membrane is ready to be used to cover the graft before closing the flap.

u An insulin syringe with its tip trimmed off is used to speed up the placement of the graft material and thus the entire grafting process.

v The graft mixed with PRP is progressively loaded into the tuberculin syringe (I).

w The graft mixed with PRP is progressively loaded into the tuberculin syringe (II).

x The graft mixed with PRP is progressive loaded into the tuberculin syringe (III).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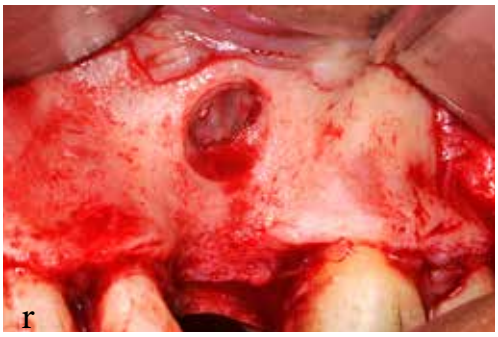
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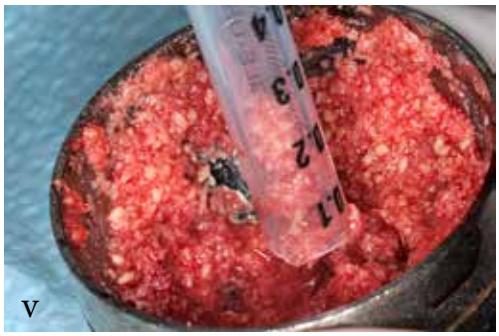
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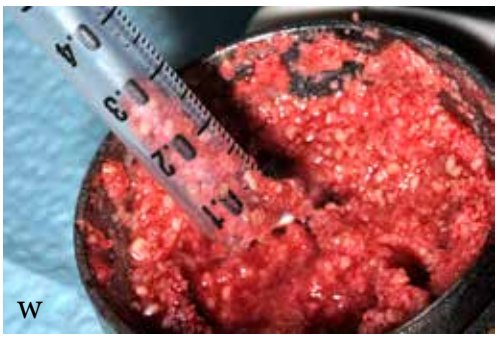
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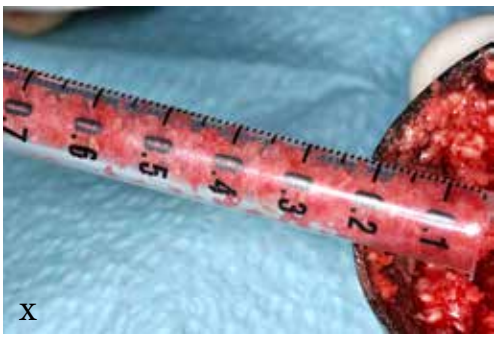
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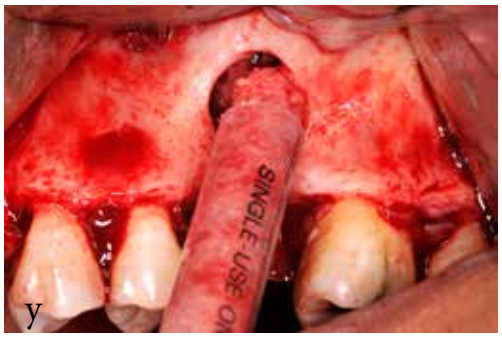
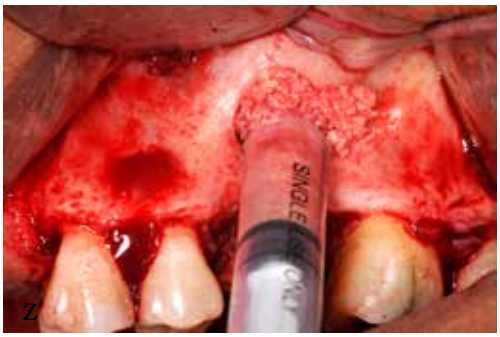
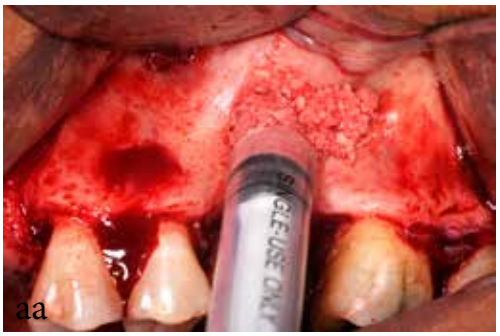
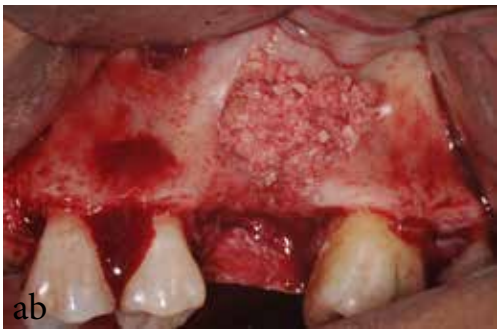
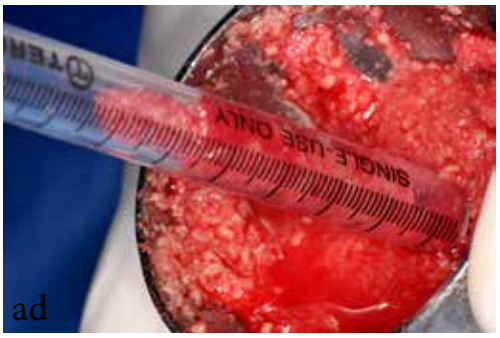
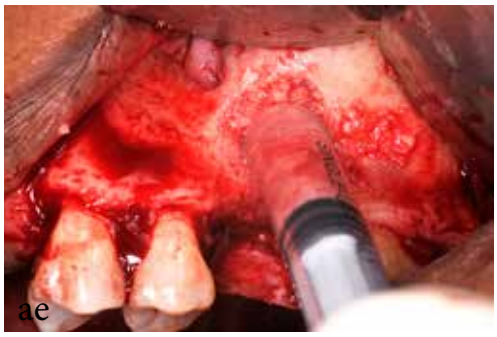


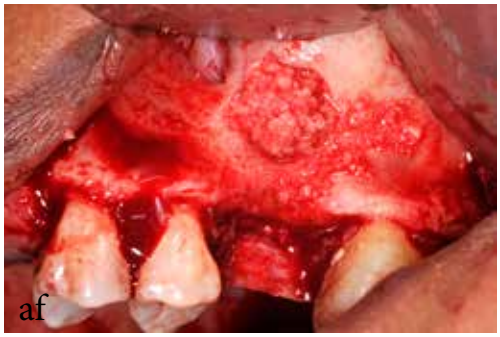


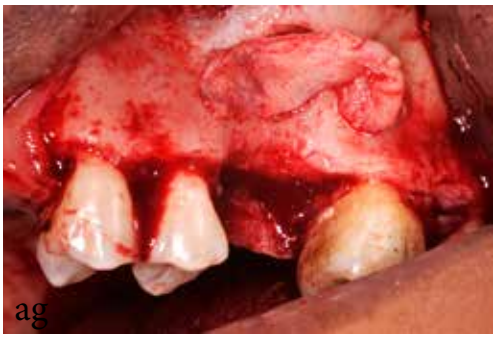












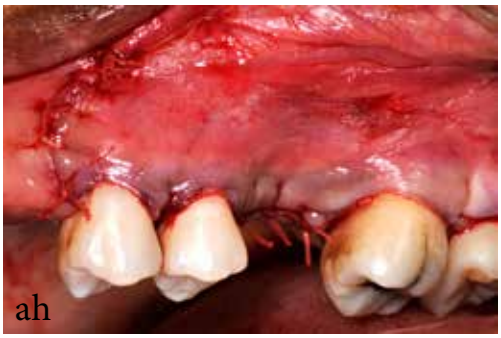


Fig. 5-21 (cont'd)

y Initial filling.The syringe is used to deliver the bone into the sinus cavity (I).

z Initial filling.The syringe is used to deliver the bone into the sinus cavity (II).

aa Initial filling.The syringe is used to deliver the bone into the sinus cavity (III).

ab Partial filling of the sinus cavity.

ac Graft material is gently compacted in all directions.

ad Reload of the syringe in order to repeat the process until the cavity is fully filled.

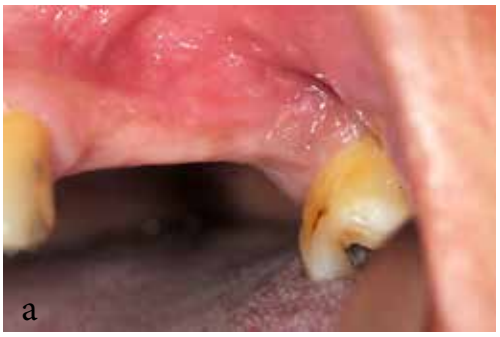
ae Last load of graft material.

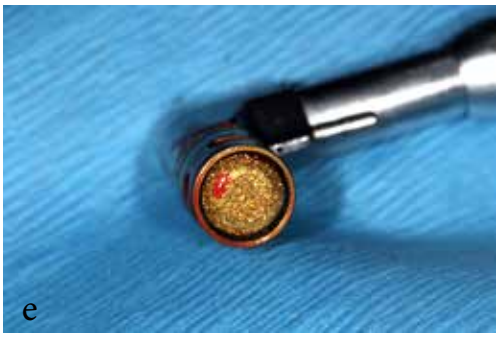
af Antral cavity fully filled.

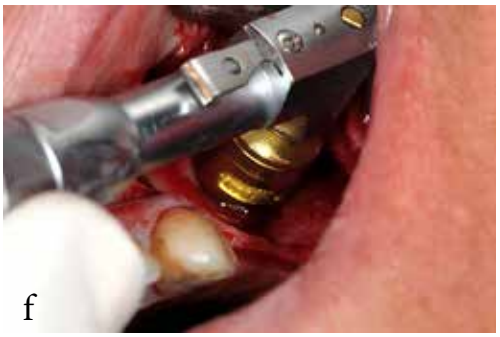
ag Coverage of the graft with a PRP membrane.

ai Flap repositioned in place by single interrupted sutures.

Notes







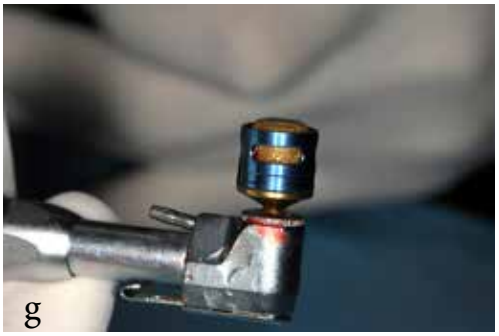


Fig. 5-22

Lateral Wall Sinus Lift using Special Burs

a Clinical pre-operative view.

b Full-thickness flap refection.

c Dome shaped diamond bur.

d Diamond bur with 0.5 mm stopper (I).

e Diamond bur with 1 mm stopper (II).

f Initial Osteotomy using 1 mm stopper.

g 1 mm stopper in place.

h Initial Osteotomy using 1 mm stopper (I).

Fig. 5-22 (cont'd)

i Initial Osteotomy using 1 mm stopper (II).

j 2 mm stopper in place.

k Initial osteotomy using 2 mm stopper (I).

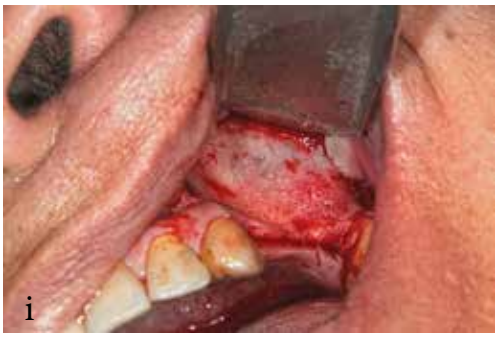
l Initial osteotomy using 2 mm stopper (II)

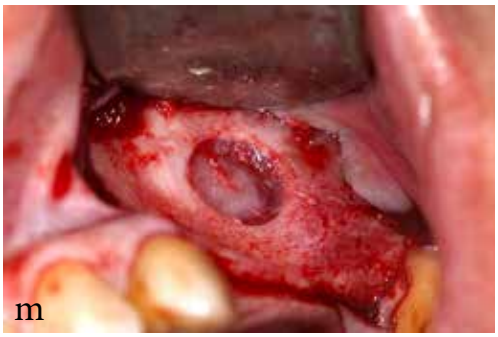
m Final osteotomy using 2 mm stopper (III)

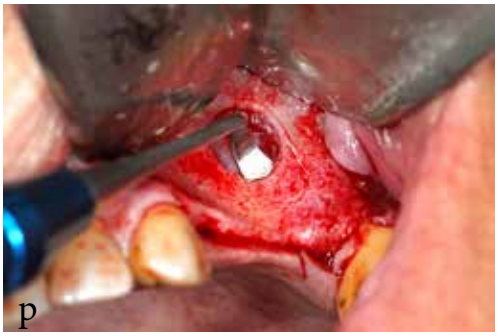
n Initial detachment of membrane using special curettes.

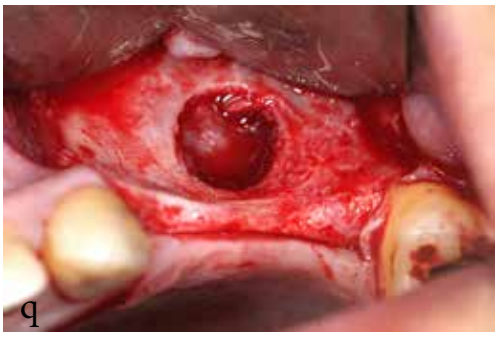
o Initial detachment of membrane from the mesial.

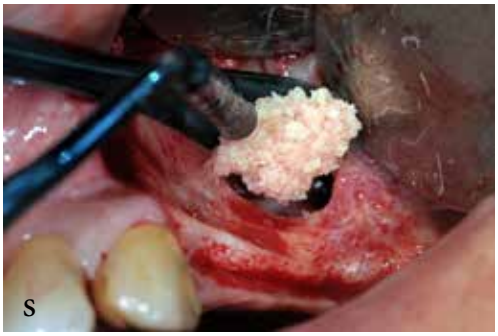
p Initial detachment of membrance from the distal.

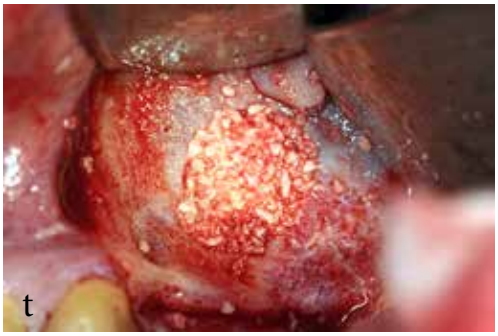


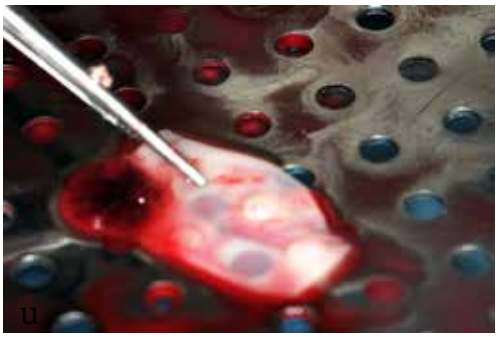












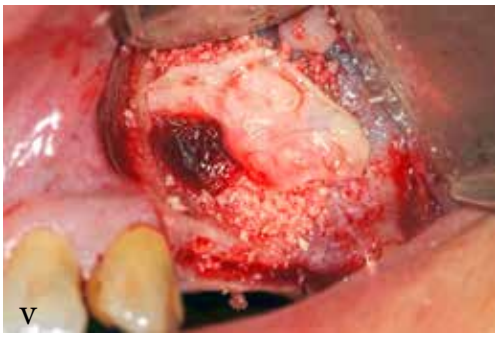


Fig. 5-22 (cont'd)

q Final detachment of the sinus membrane completed.

r The cortical-cancellous allogenic bone graft is poured in a mixing cup and is mixed with the patient's PRP.

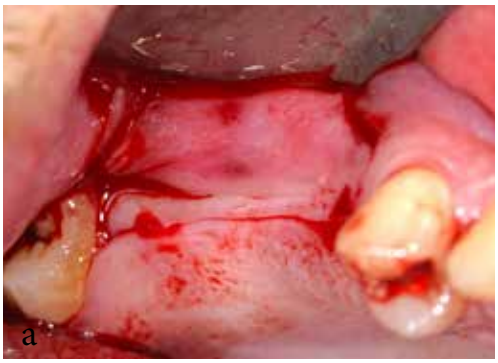
s Mixed graft gently packed into sinus cavity.

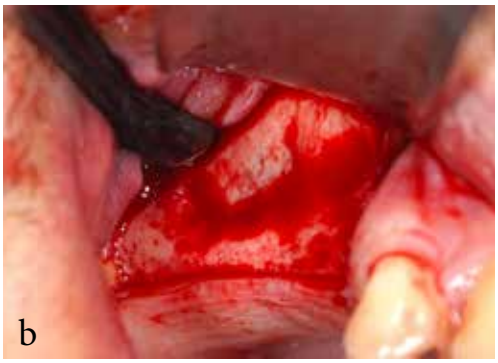
t Sinus cavity fully grafted.

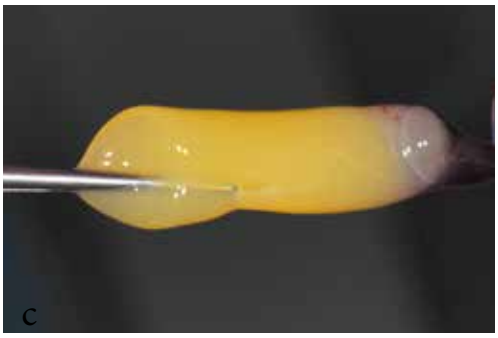
u PRP membrane ready for use.

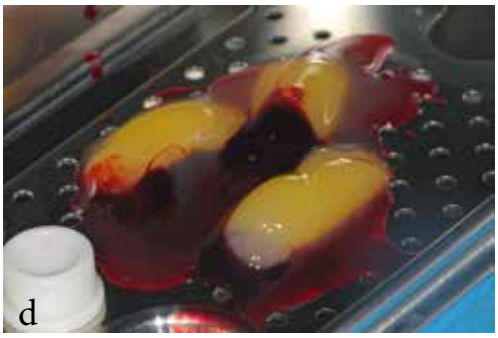
v Coverage of graft with PRP membrane.

Notes









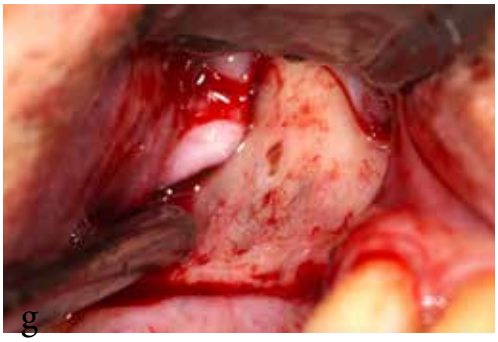


Fig. 5-23

a Clinical pre-operative view.

b Full-thickness flap refection

c The PRP membrane as it is obtained from the blood test tube.

d The PRP Membrane Kit is designed to reduce the thickness and to increase the size of the original PRP membrane.

e Dome shaped diamond bur.

f Diamond bur with 0.5 mm stopper.

g Initial osteotomy.

Fig. 5-23 (cont'd)

h Initial detachment of Sinus membrane using special currettes.

i Enlargement of the initial osteotomy using the same bur (I).

j Enlargement of the initial osteotomy using the same bur (II).

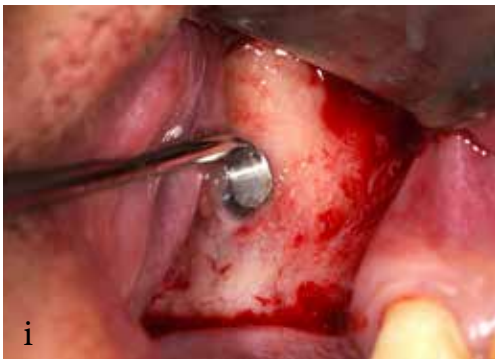
k Enlargement of the initial osteotomy using the same bur (III).

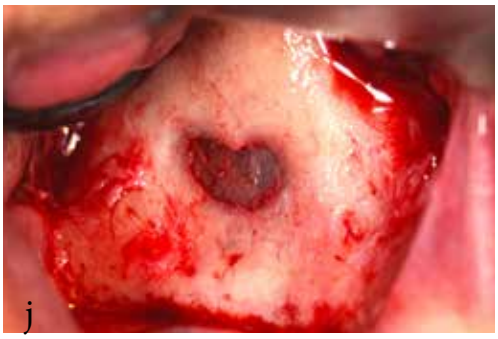
l Final detachment of the sinus membrane completed.

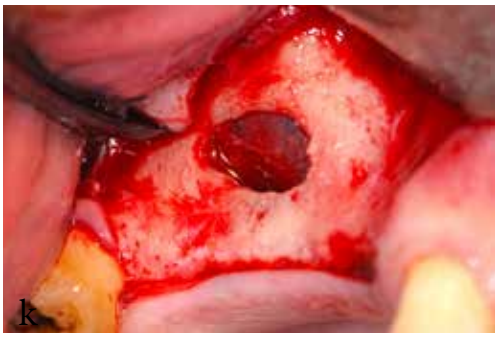
m The cortical-cancellous allogenic bone graft is poured in a mixing cup and is mixed with the patient's PRP (I).

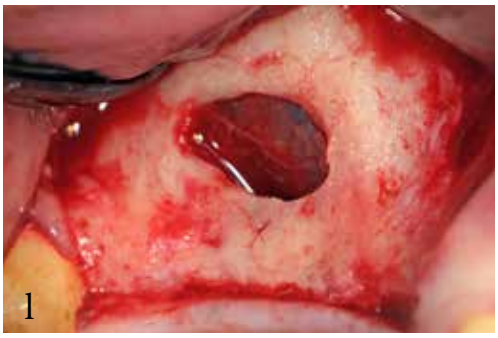
n The cortical-cancellous allogenic bone graft is poured in a mixing cup and is mixed with the patient's PRP (II).

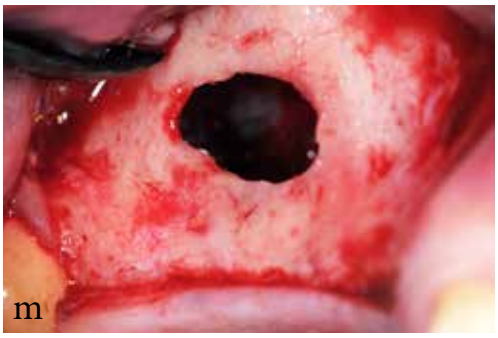
o The mix is progressive loaded in a tuberculin syringe.

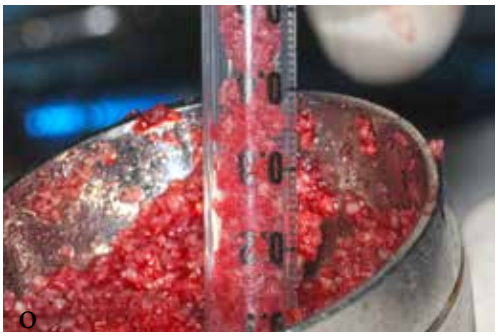


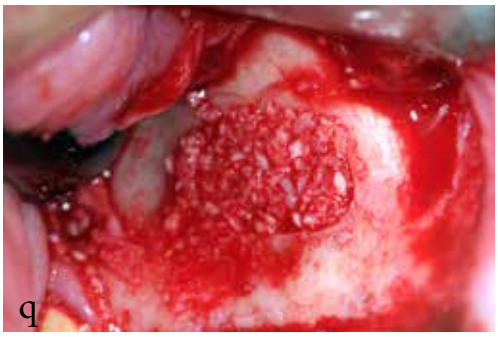


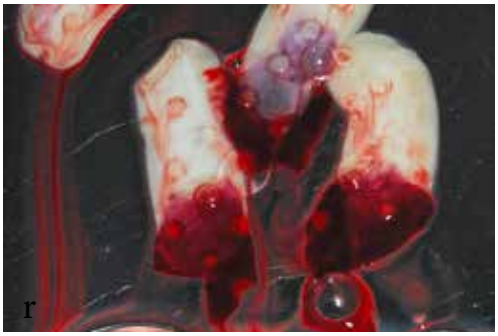












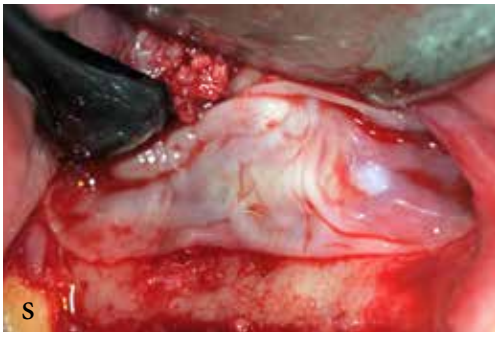


Fig. 5-23 (cont'd)

p Initial filling.The tuberculin syringe is used to deliver the bone into the sinus cavity.

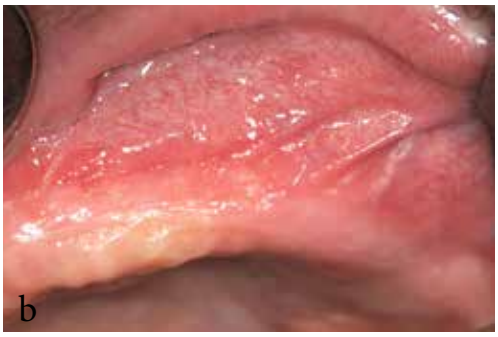
q Antral cavity fully filled.

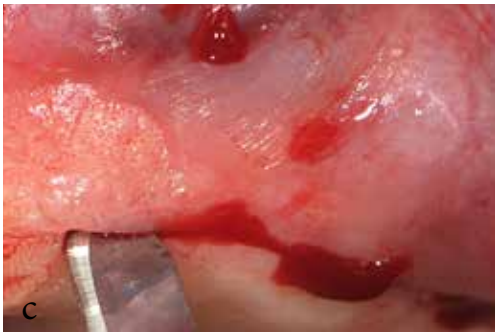
r PRP membranes ready for use.

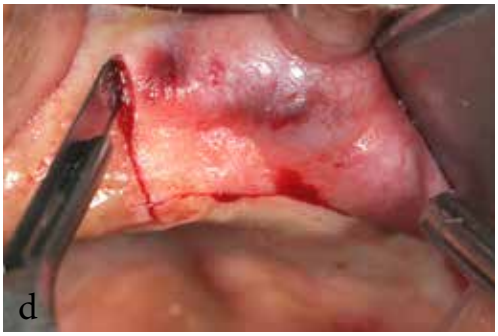
s Coverage of the graft with a PRP membrane.

t Flap repositioned in place by single interrupted sutures.

Notes







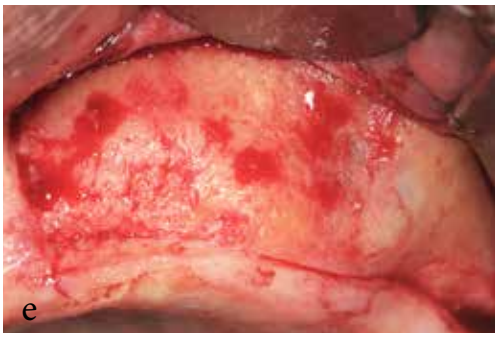


Fig. 5-24

a Phlebotomy to obtain patient's own blood.

b Clinical pre-operative view.

c Crestal incision slighty to the palate.

d The buccal releasing incision is connected with the horizontal palatal incision.

e Full-thickness flap refection.

f The PRP membrane as it is obtained from the blood test tube.

g The PRP Membrane Kit is designed to reduce the thickness and to increase the size of the original PRP membrane (I).

h The PRP Membrane Kit is designed to reduce the thickness and to increase the size of the original PRP membrane (II).

Fig. 5-24 (cont'd)

i The new kit for lateral wall sinus approach provides stoppers for a large bur: the 1.0 mm stopper.

j The 1.5 mm stopper.

k The 2.0 mm stopper.

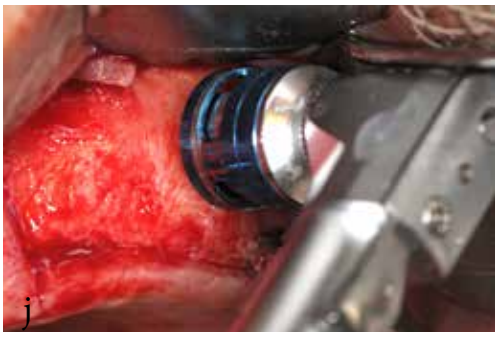
l The 2.5 mm stopper.

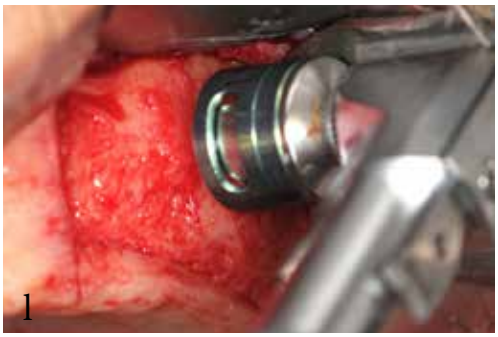
m The osteotomy starts by using the large bur with the 1.0 mm stopper.

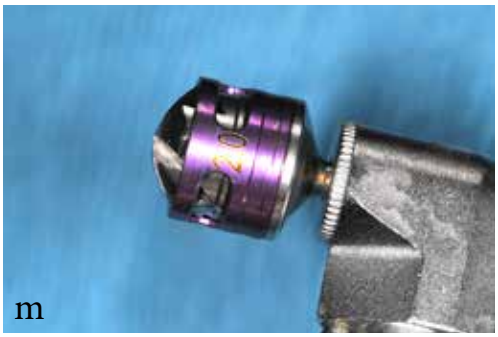
n The large bur with the 1.5. mm stopper goes next.

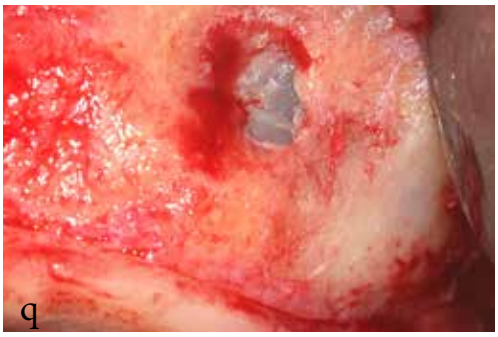
o Then the large bur with the 2.0 mm stopper is used.

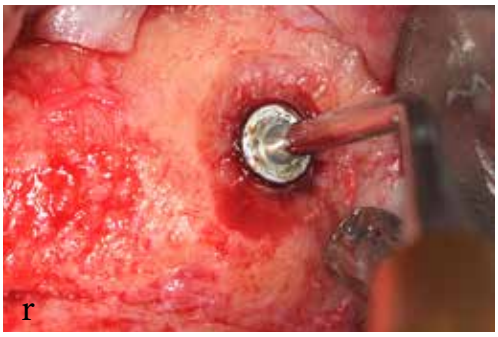
p The large bur with the 2.5 mm stopper is used the last.

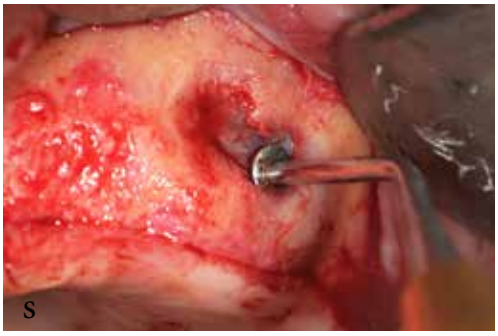


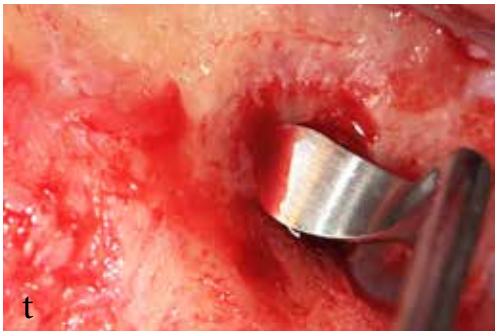












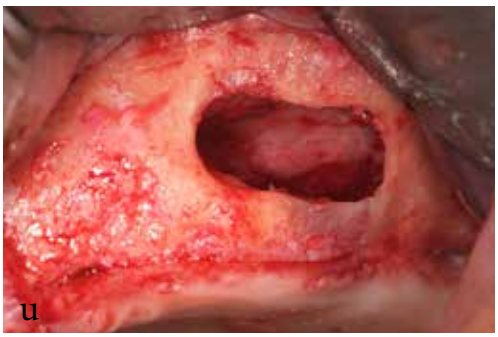


Fig. 5-24 (cont'd)

q The bur is designed to trim the bone only, leaving the membrane intact.

r To start with the initial detachment of the membrane, a specially designed curette is used.

s In order to enlarge the osteotomy, the process is repeated next to the first one.

t The complete detachment of the membrane is achieved by using the conventional sinus curettes.

u Final detachment of the membrane.

v The PRP is added to the cortical-cancellous allogenic bone graft and mixed in a cup (I).

w The PRP is added to the cortical-cancellous allogenic bone graft and mixed in a cup (II).

x The PRP is added to the cortical-cancellous allogenic bone graft and mixed in a cup (III).

Fig. 5-24 (cont'd)

y The PRP is added to the cortical-cancellous allogenic bone graft and mixed in a cup (IV).

z The mix is progressive loaded in a tuberculin syringe (I).

aa Initial filling.The syringe is used to deliver the bone into the sinus cavity.

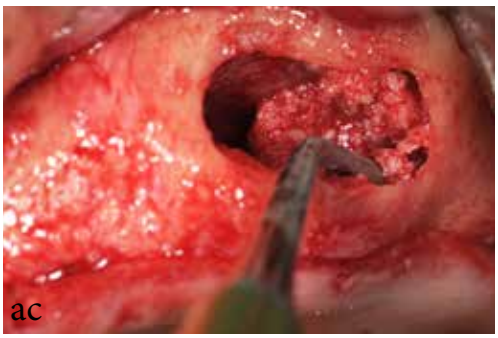
ab The bone packer tip is used to gently compact the grafted bone.

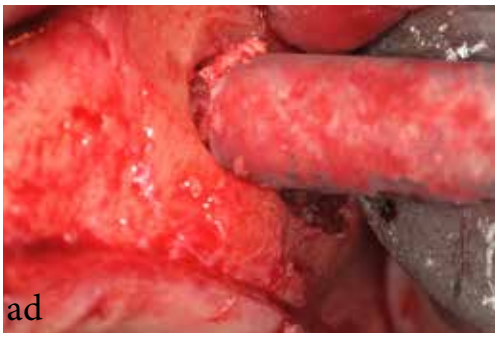
ac The graft is gently packed to the distal part of the sinus cavity.

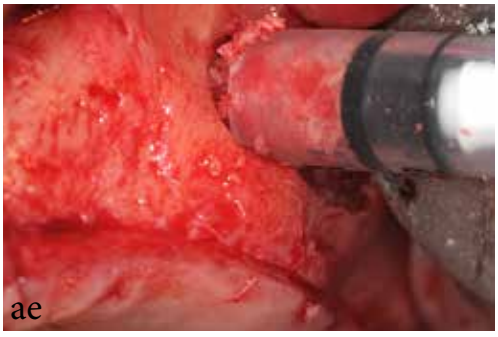
ad More bone is delivered into the mesial part of the sinus cavity(I)

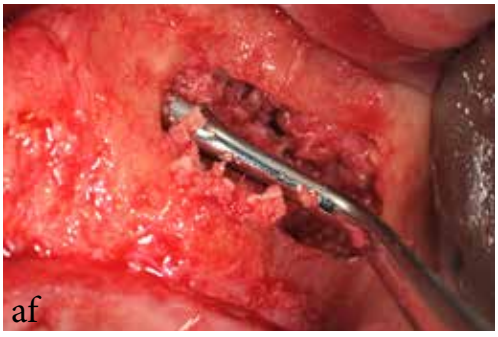
ae More bone is delivered into the mesial part of the sinus cavity(II)

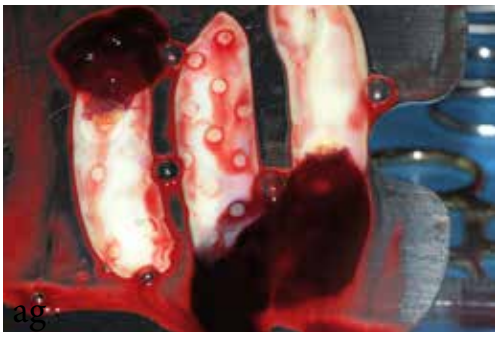
af The graft is gently packed to the mesial part of the sinus cavity.

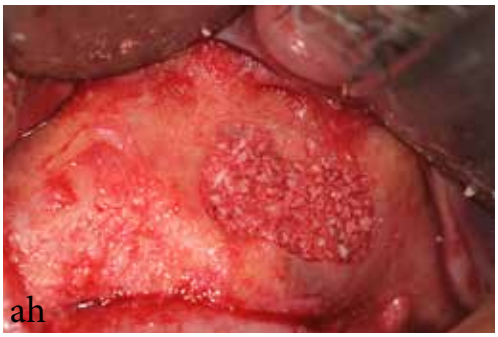


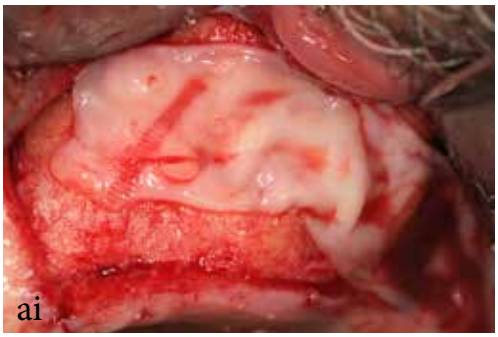


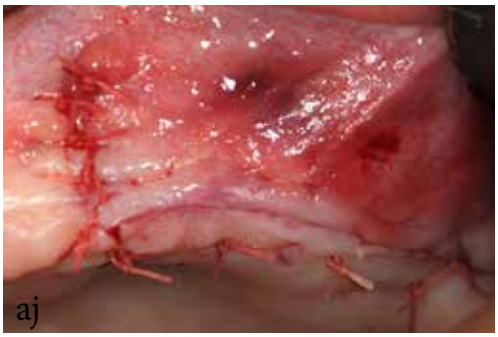












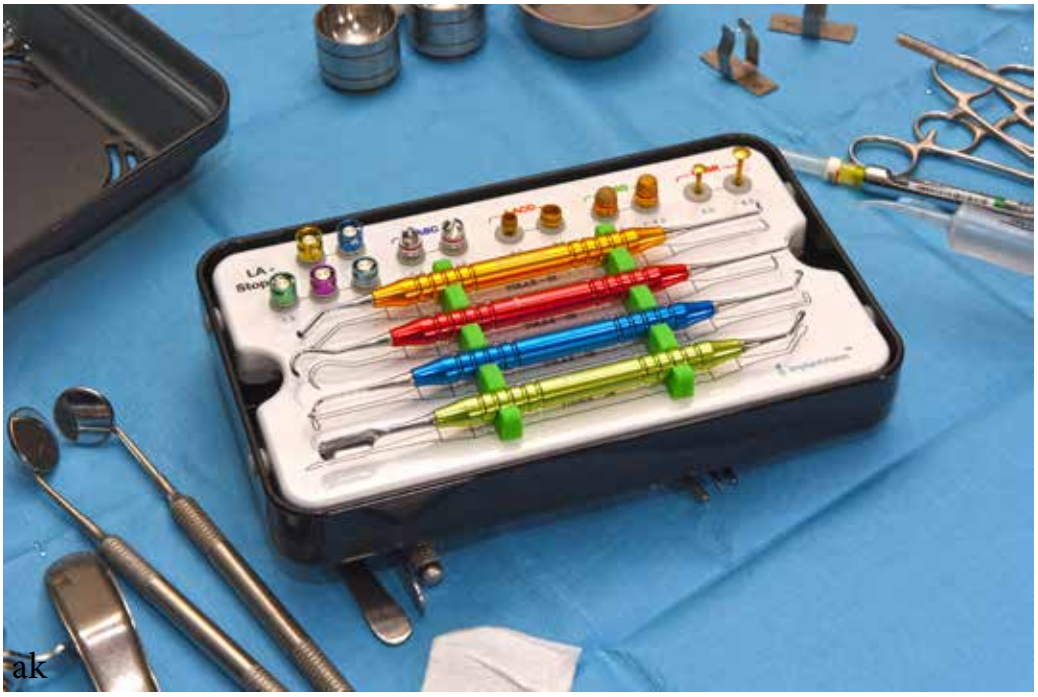


Fig. 5-24 (cont'd)

ag PRP membranes ready for use.

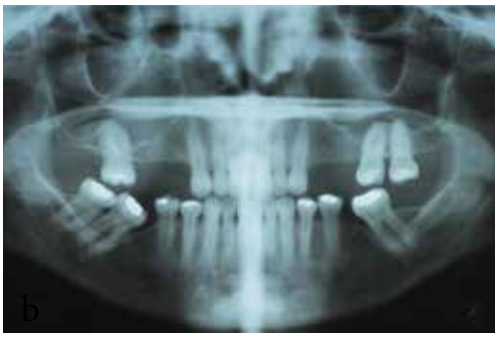
ah Antral cavity fully filled.

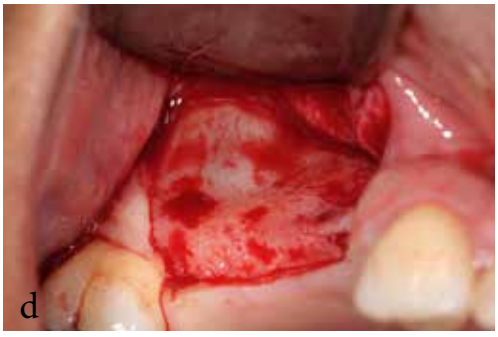
ai Coverage of the graft with a PRP membrane.

aj Flap repositioned in place by single interrupted sutures.

ak The complete New Kit for Lateral Wall approach: burs, stoppers and sinus curettes.

Notes





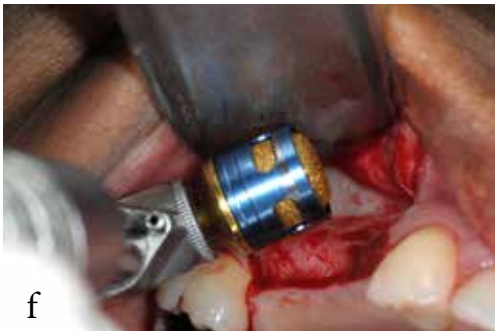


Fig. 5-25

a Phlebotomy to obtain patient's own blood.

b Radiographic pre-operative view.

c Clinical pre-operative view.

d Full-thickness flap refection.

e The large diamond bur with the 1.0 mm stopper (I).

f The large diamond bur with the 1.0 mm stopper (II).

g initial osteotomy after using the large diamond bur with the 1.0 stopper.

Fig. 5-25 (cont'd)

h The PRP membranes as they are obtained from the blood test tube.

i The PRP Membrane Kit is designed to reduce the thickness and to increase the size of the original PRP membrane.

j The kit provides expanded membranes of a consistent thickness.

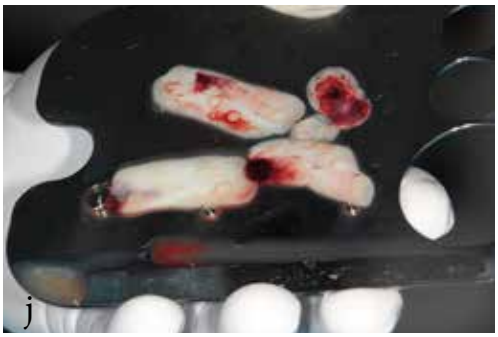
k The initial osteotomy is then enlarged using a round diamond bur.

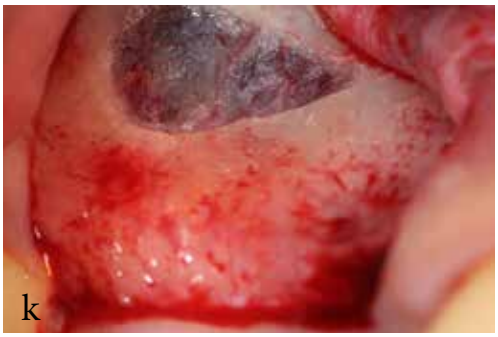
l Initial detachment of the membrane from the distal side.

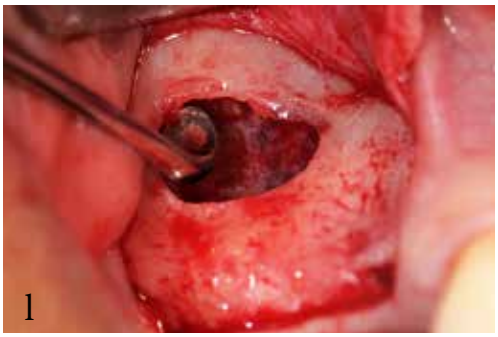
m Initial detachment of the membrane from the sinus floor.

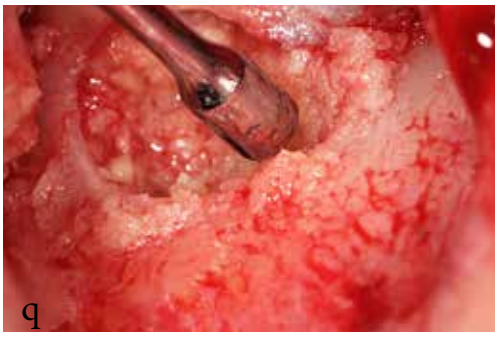
n Final detachment of the membrane.

o The PRP is added to the cortical-cancellous allogenic bone graft and mixed in a cup









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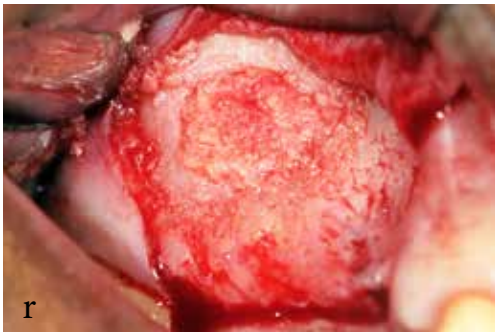

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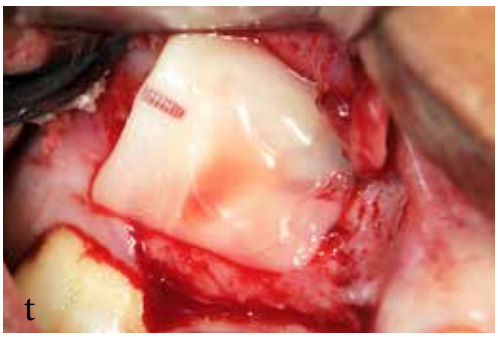


t

u

Fig. 5-25 (cont'd)

p The mix is progressive loaded into the sinus cavity and gently packed in all directions.

q More bone is added to the central part of the sinus cavity.

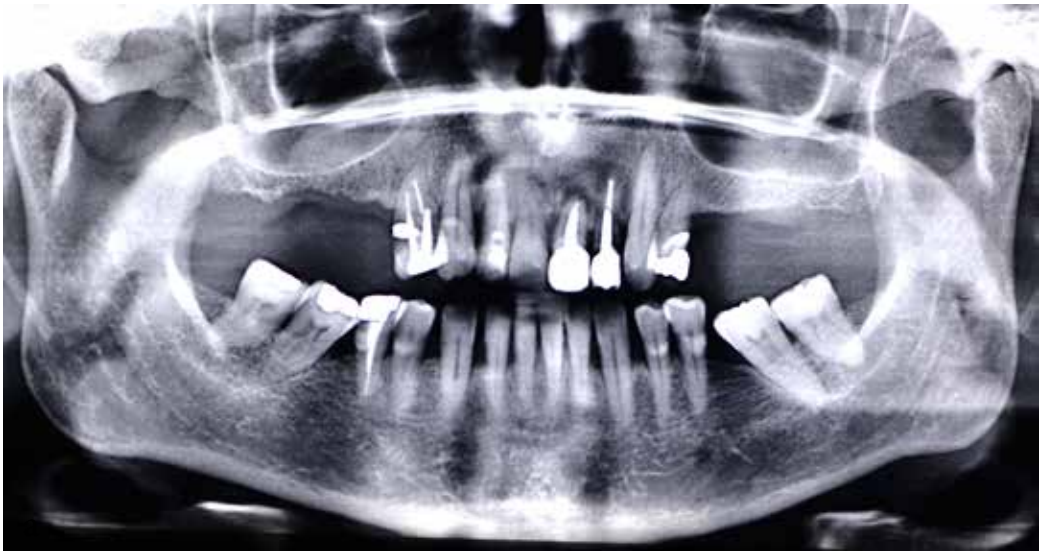
r Antral cavity fully filled.

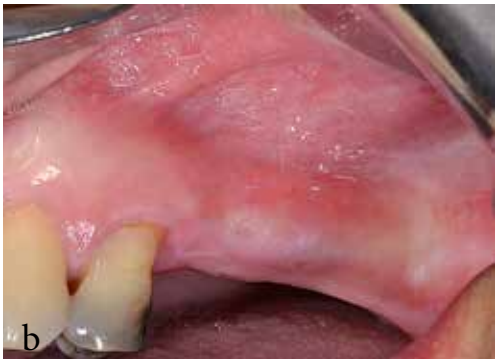
s PRP membrane ready for use.

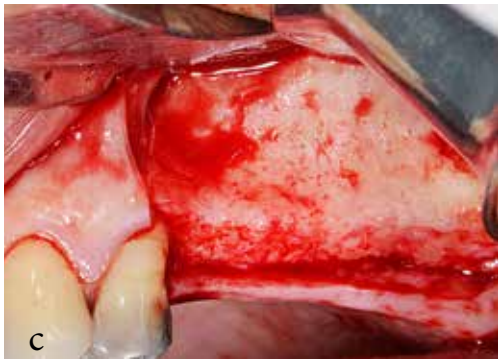
t Coverage of the graft with a PRP membrane.

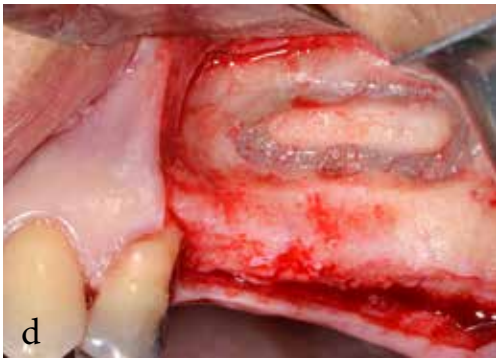
u Flap repositioned in place by single interrupted sutures.

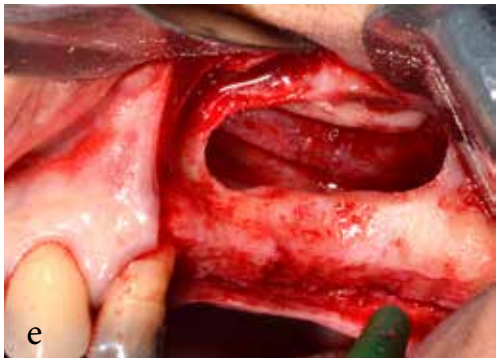
Notes











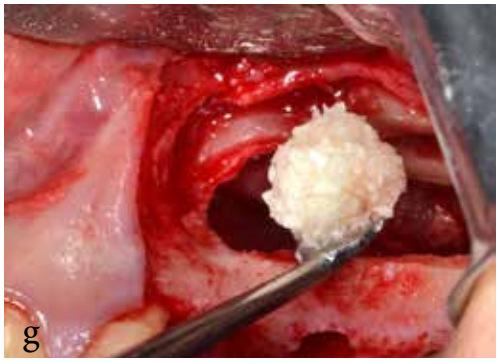


Fig. 5-26

a Radiographic pre-operative view.

b Clinical pre-operative view.

c Full-thickness flap refection.

d Initial osteotomy. Notice the horizontal oval shape.

e Final osteotomy and membrane detachment.

f Implants osteotomies completed.

g Bone is delivered into the sinus cavity using a Molt curette.

Fig. 5-26 (cont'd)

h Bone is packed against the medial wall to create the palatal bony wall of the implants

i Future palatal bony wall of implants complete.

j implants placement.

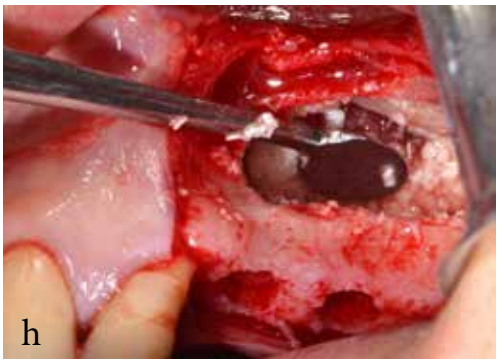
k The lateral wall of the sinus has become the new roof of the grafted sinus

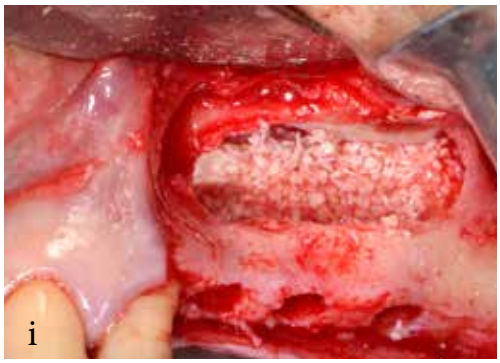
l More bone is added and gently packed between the implants.

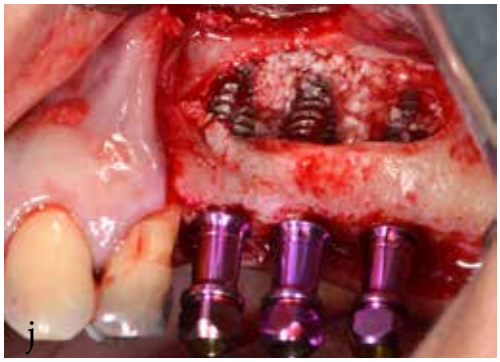
m Antral cavity fully filled with cortical Coverage of graft material with a resorbable xenogenic collagen membrane.

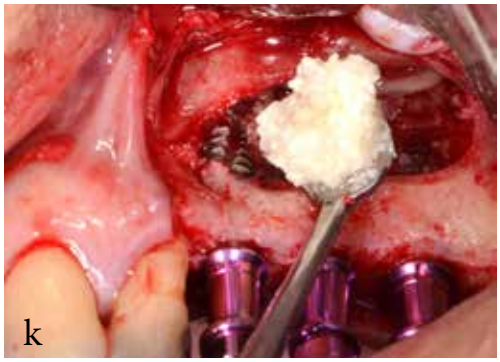
n Status of soft tissues around implants immediately before taking the final impression.

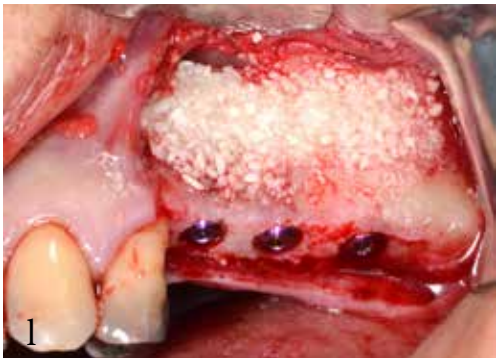
o Clinical view of the cemented implant bridge.

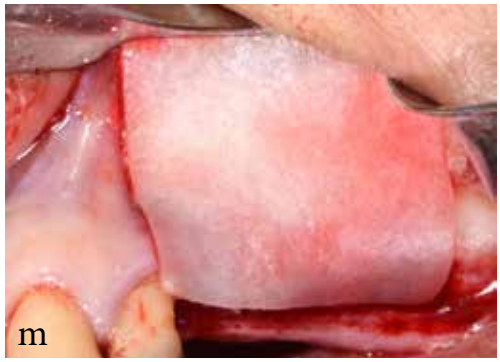


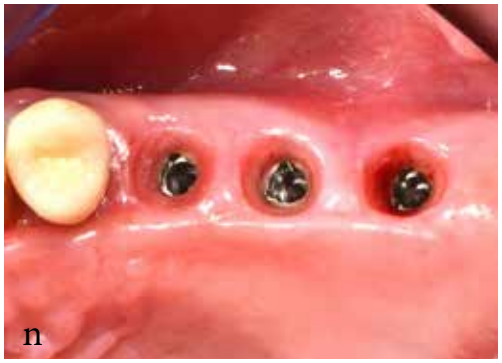


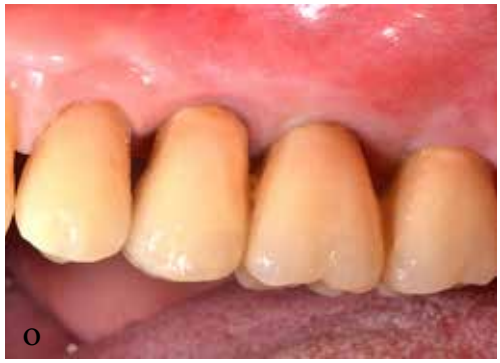












Notes

Fig. 5-27

a Radiographic pre-operative view.

b Radiographic close-up view of left sinus.

c Clinical pre-operative view.

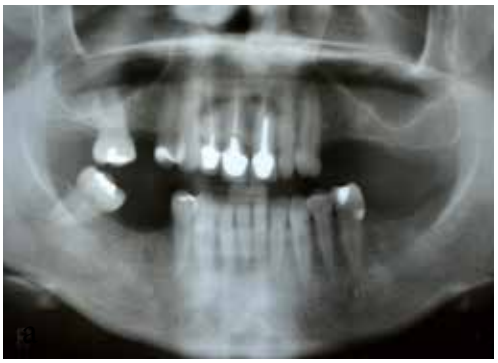
d Full-thickness flap refection. Sinus cavity is evident.

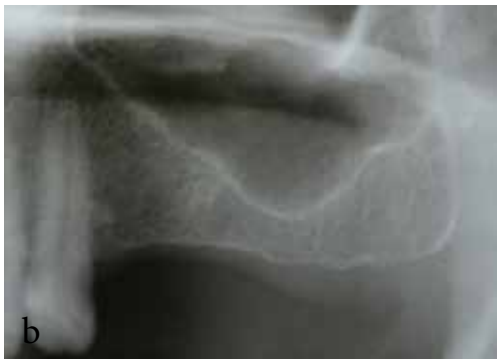
e Initial osteotomy. Notice the horizontal circular shape.

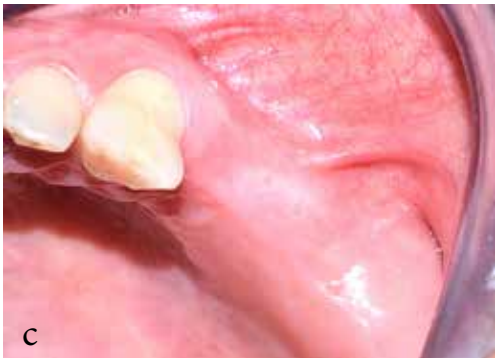
f Enlarged final osteotomy and membrane detachment.

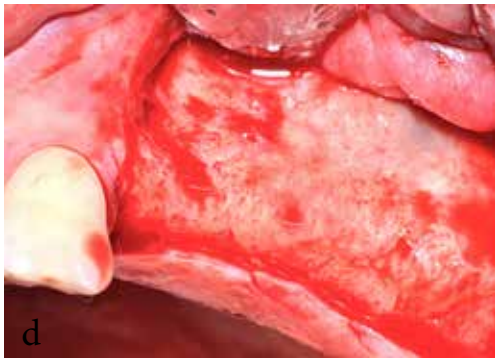
g Implants osteotomies completed.

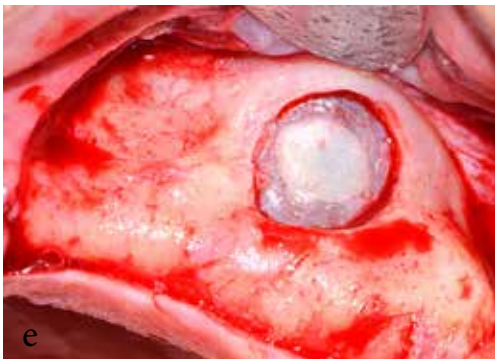
h Bone is packed against the medial wall to create the palatal bony wall of the implants

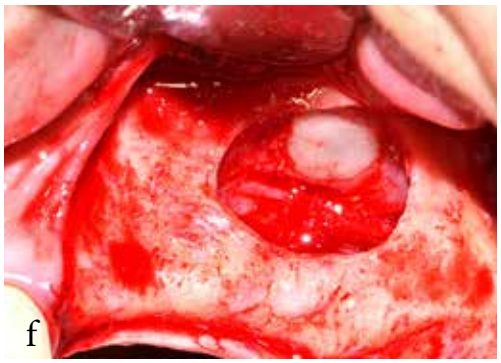


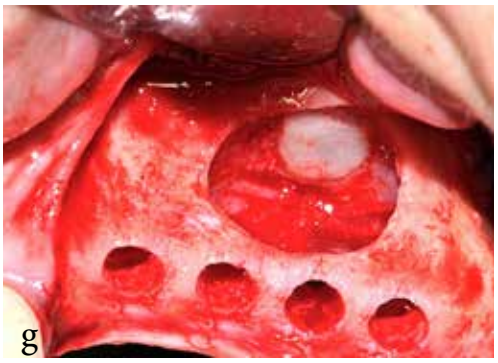


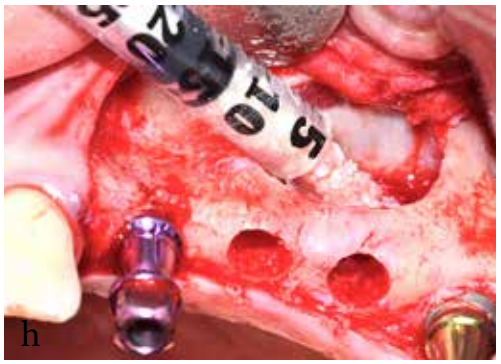


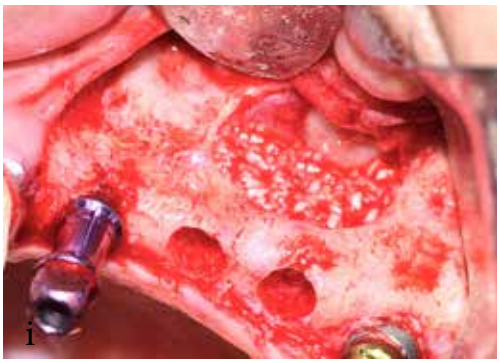


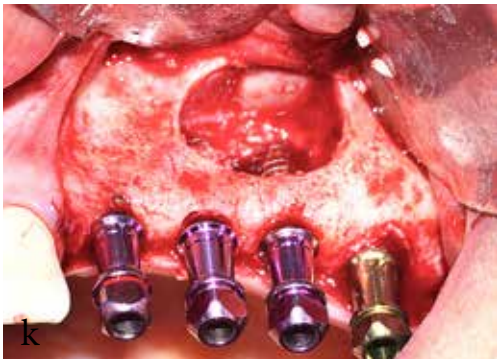


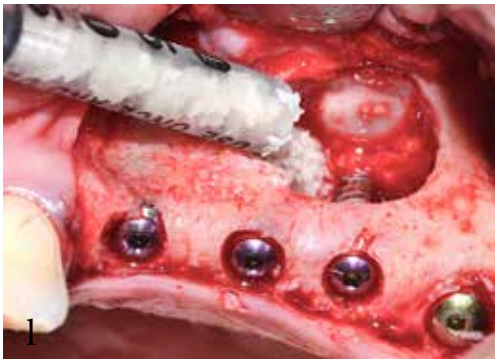


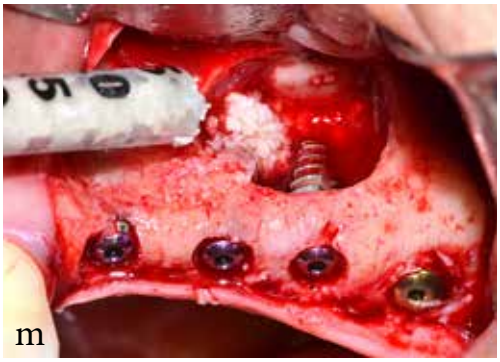












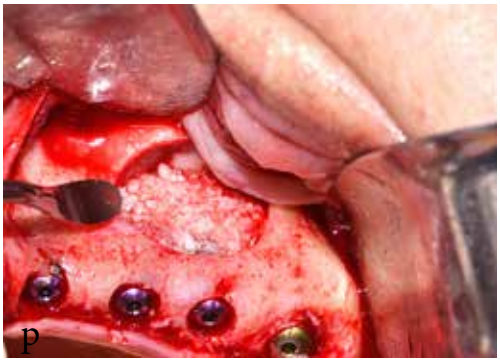


Fig. 5-27 (cont'd)

i Future palatal bony wall of implants complete.

j Implants placement.

k The lateral wall of the sinus has become the new roof of the grafted sinus.

l Bone is added using a tuberculin syringe.

m A tuberculin syringe can carry a significant amount of bone all at once(I)

n A tuberculin syringe can carry a significant amount of bone all at once(II)

o A tuberculin syringe can carry a significant amount of bone all at once(III)

p Bone is gently packed between the implants.

Fig. 5-27 (cont'd)

q More bone is added in the buccal aspect of the implants(I).

r More bone is added in the buccal aspect of the implants(II).

s More bone is added in the buccal aspect of the implants(III).

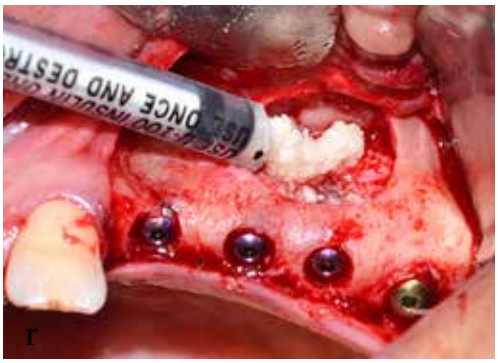
t Bone is gently packed over the buccal aspect of the implants.

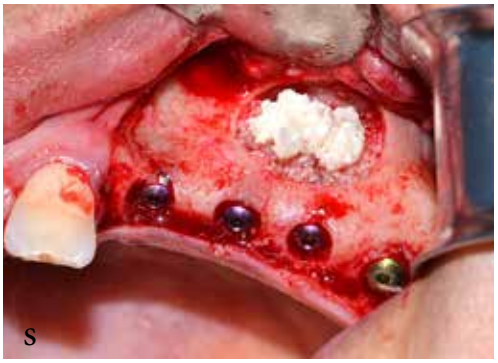
u Antral cavity fully filled with cortical allogenic bone graft.

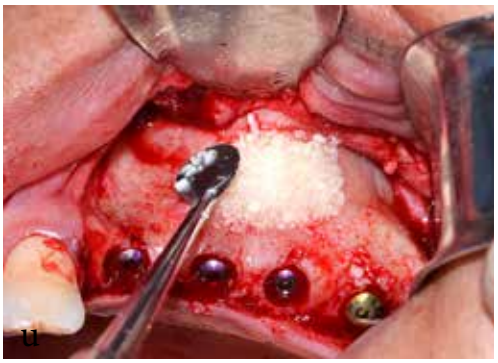
v Coverage of graft material with a resorbable xenogenic collagen membrane.

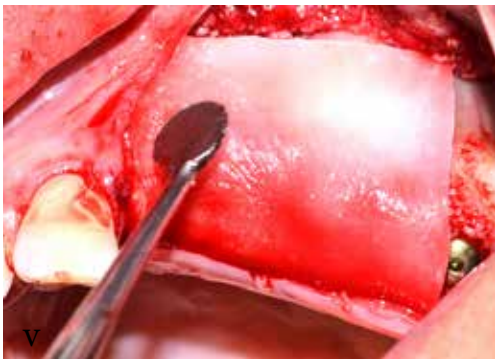
w Radiographic post-operative view of oseointegrated implants immediately after healing abutment connections.

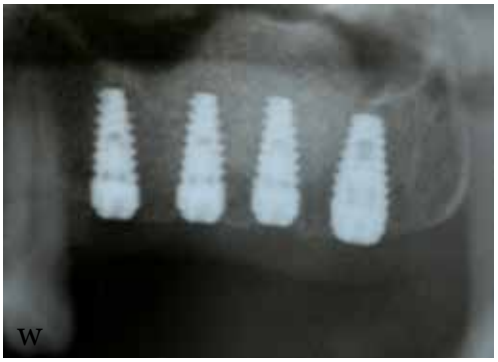
x Status of soft tissues around implants immediately before taking the final impression.

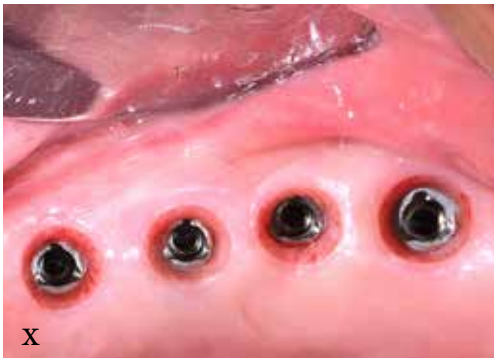


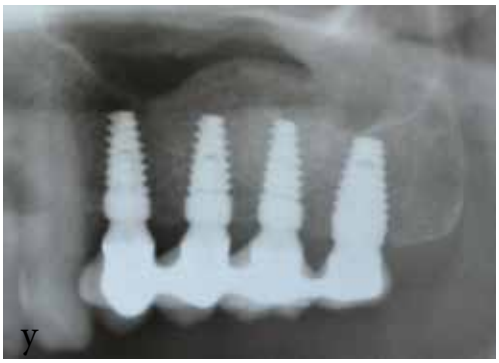












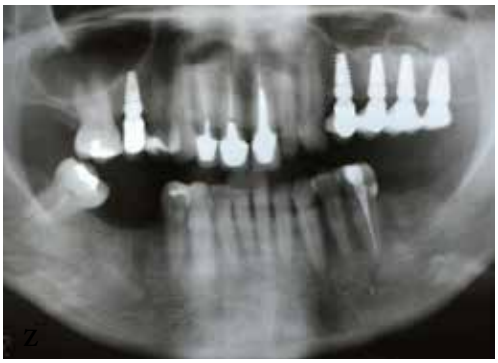


Fig. 5-27 (cont'd)

y Radiographic view of implants immediately after bridge cementation.

z One-year radiographic postoperative follow-up view.

Notes

Fig. 5-28

a Radiographic pre-operative view.

b Radiographic close-up view of the area of the sinus to be grafted.

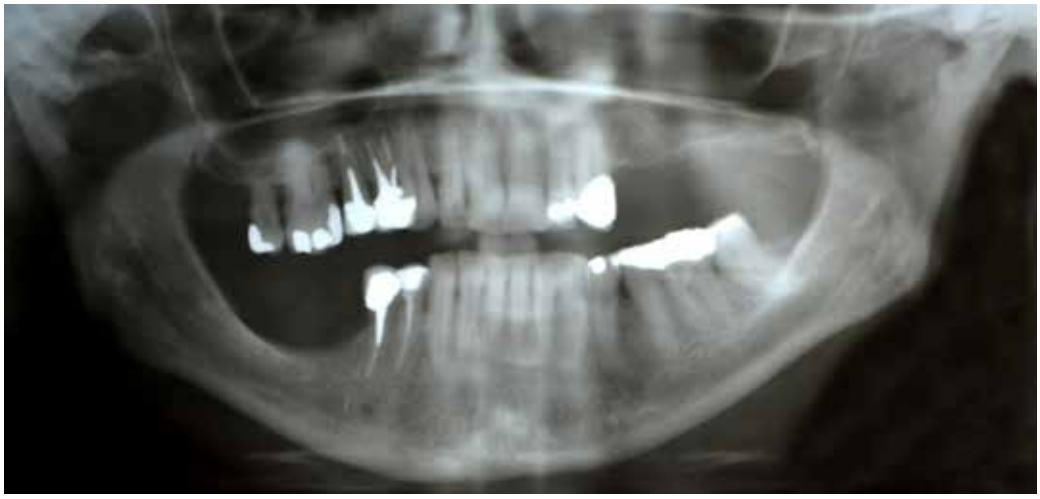
c Clinical pre-operative view.

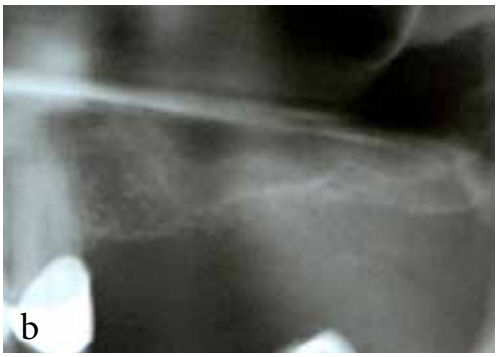
d Full-thickness flap refection.

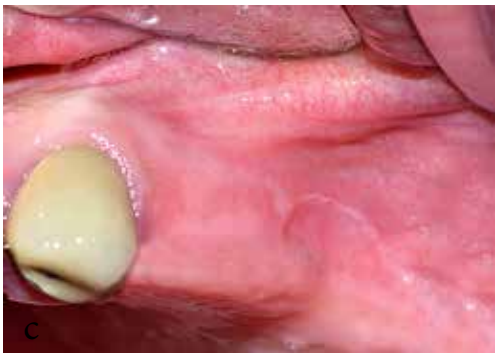
e Final osteotomy. Notice the horizontal oval shape.

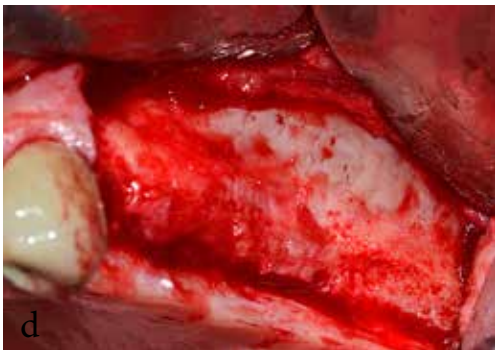
f Initial detachment of the membrane using a sinus curette.

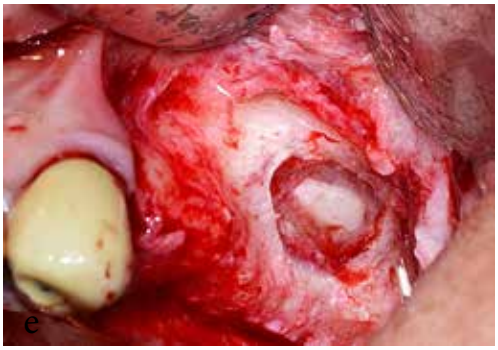
g Large perforation of the sinus membrane.

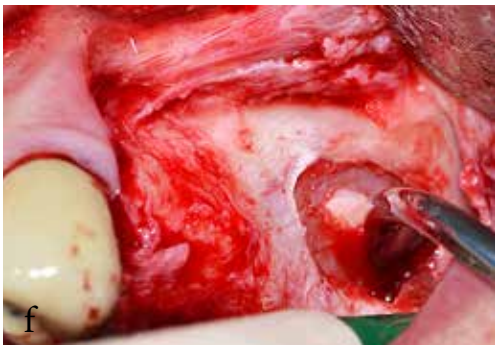


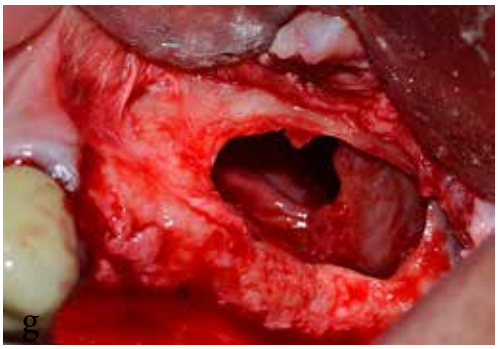


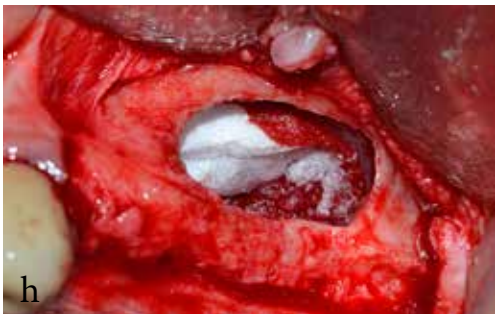


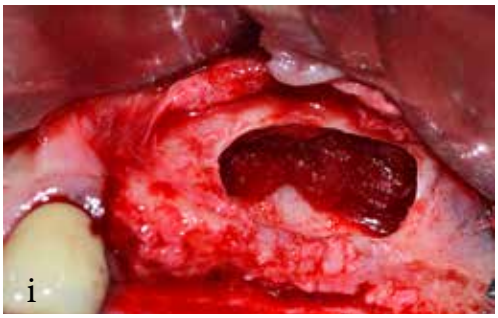


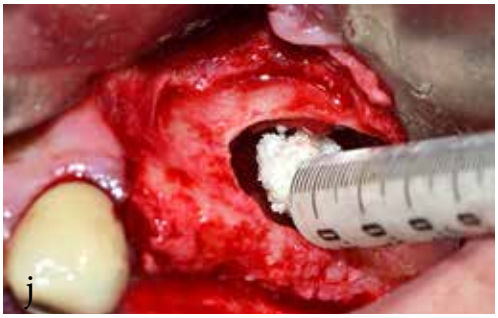


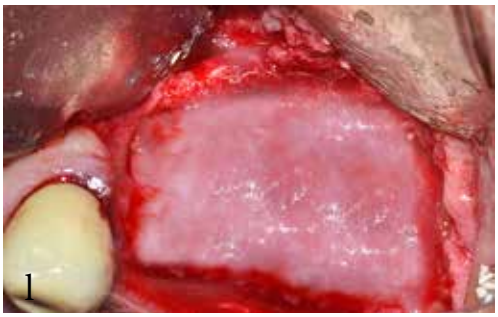


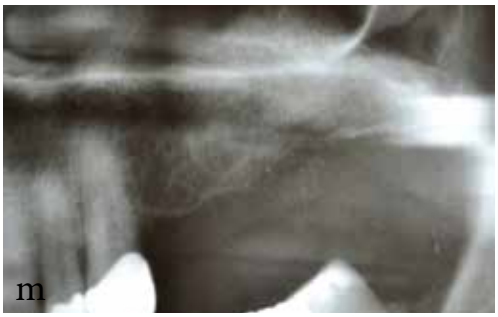












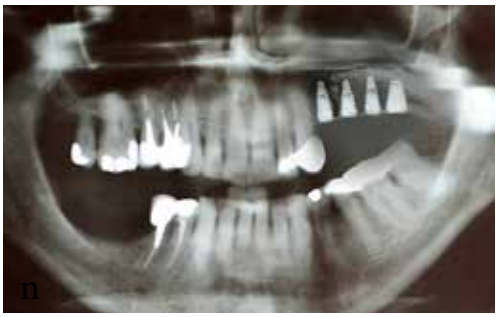


Fig. 5-28 (cont'd)

h The perforation is repaired using a resorbable xenogenic collagen membrane.

i The membrane is lifted further to create appropriate space for the graft.

j Bone is delivered into the sinus cavity using a tuberculin syringe.

k A large sinus may require several syringes in order to be fully filled.

l Coverage of graft material with a resorbable xenogenic collagen membrane.

m Radiographic post-operative close-up view of grafted sinus immediately before implant placement.

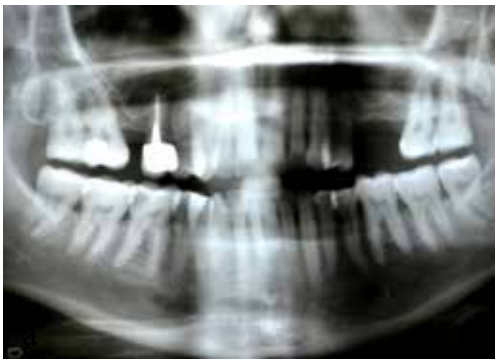
n Radiographic post-operative view of implants immediately before healing abutment connections.

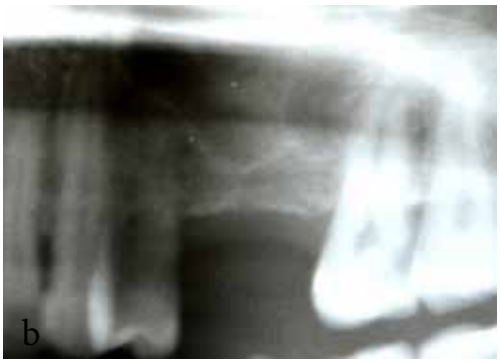
o Status of soft tissues around implants immediately before tacking the final impression.

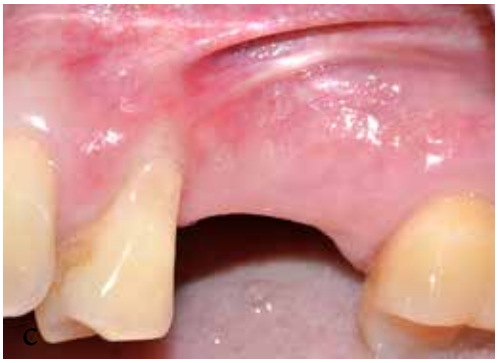
p Implant abutments before cementation of crowns.

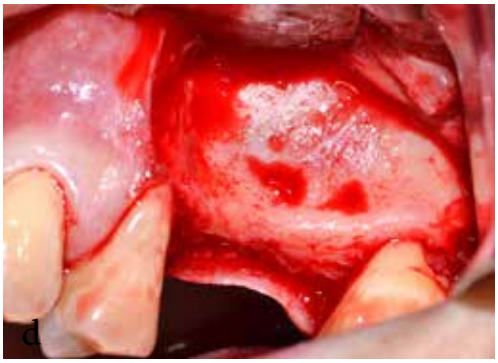
q Clinical view of the bridge cemented in place.

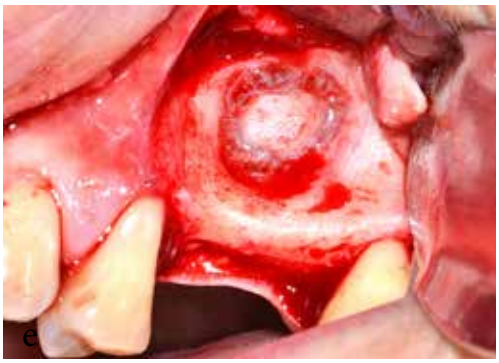
Notes

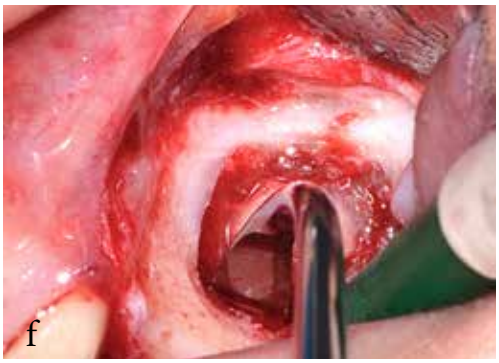


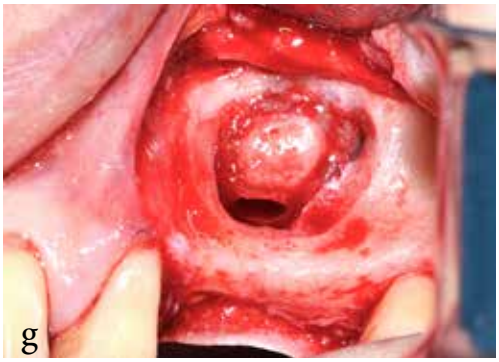












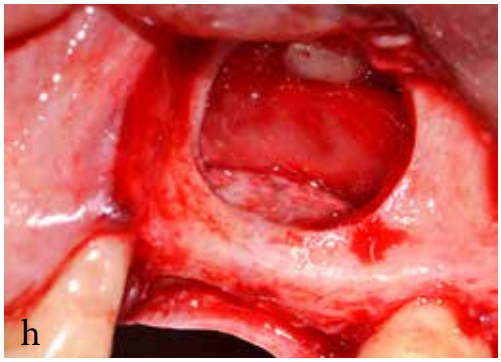


Fig. 5-29

a Radiographic pre-operative view.

b Radiographic close-up view of the area of the sinus to be grafted.

c Clinical pre-operative view.

d Full-thickness flap refection. Sinus cavity is evident.

e Initial osteotomy. Notice the vertical oval shape.

f Initial detachment of the membrane using a sinus curette.

g Small perforation of the sinus membrane.

h The osteotomy is enlarged, the membrane is lifted further to create appropriated space for the graft, and the perforation is repaired using a resorbable xenogenic collagen membrane.

Fig. 5-29 (cont'd)

i Bone is delivered into the sinus cavity using a Molt curette.

j Graft material is gently compacted in all directions.

k Antral cavity fully filled with cortical allogenic bone graft.

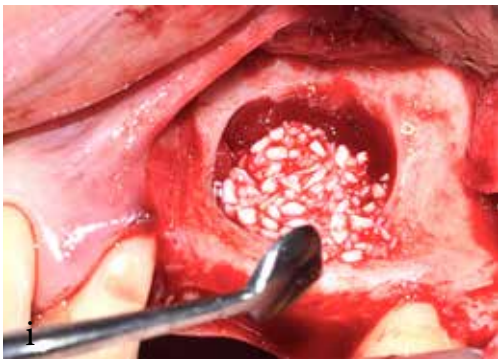
l Coverage of graft material with a resorbable xenogenic collagen membrane.

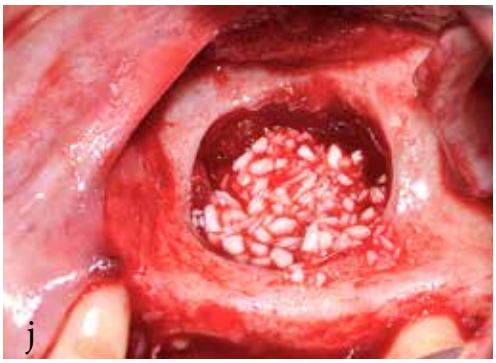
m Radiographic post-operative view of grafted sinus immediately before implant placement.

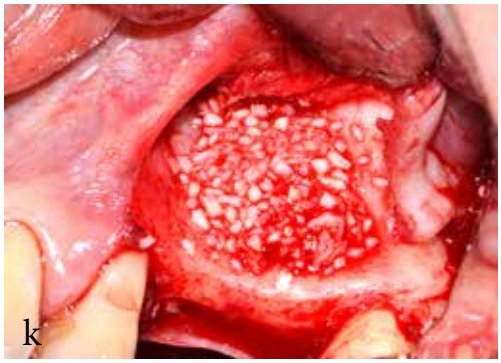
n Radiographic post-operative close-up view of grafted sinus immediately before implant placement.

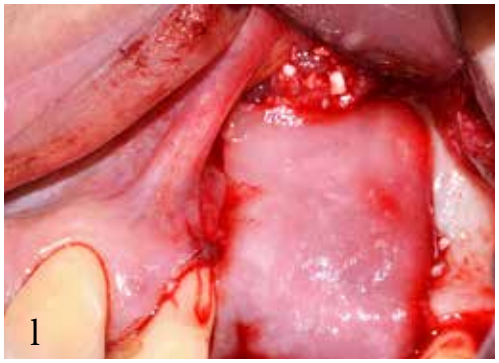
o Clinical post-operative view of grafted sinus immediately before implant placement.

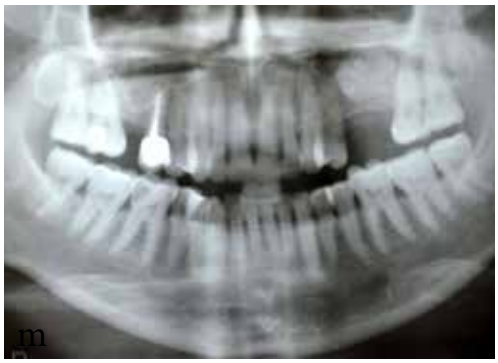
p Implants in place.

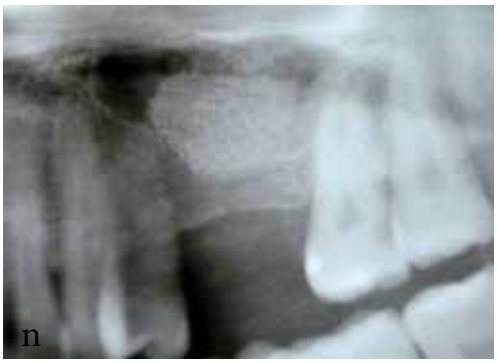


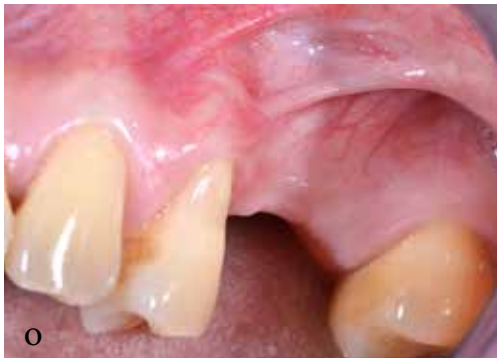


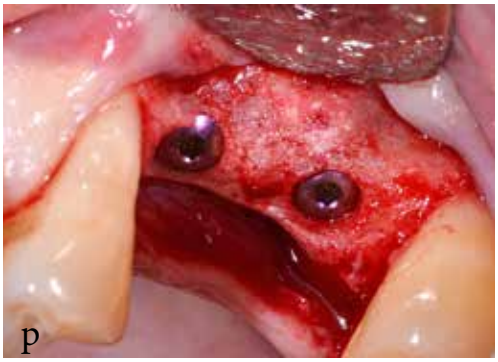


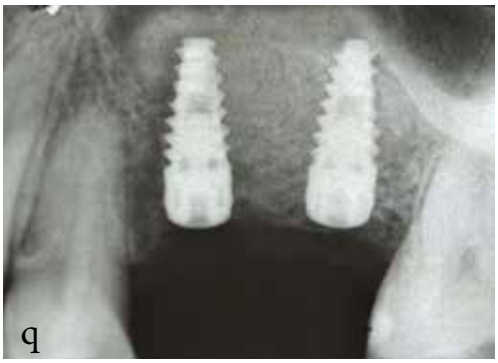












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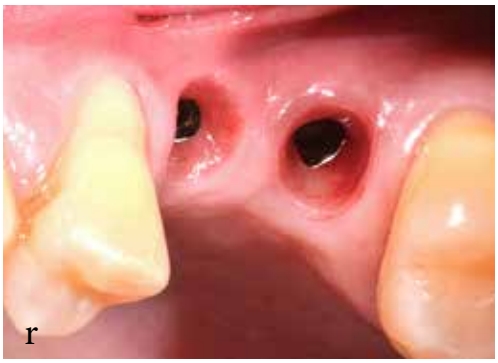

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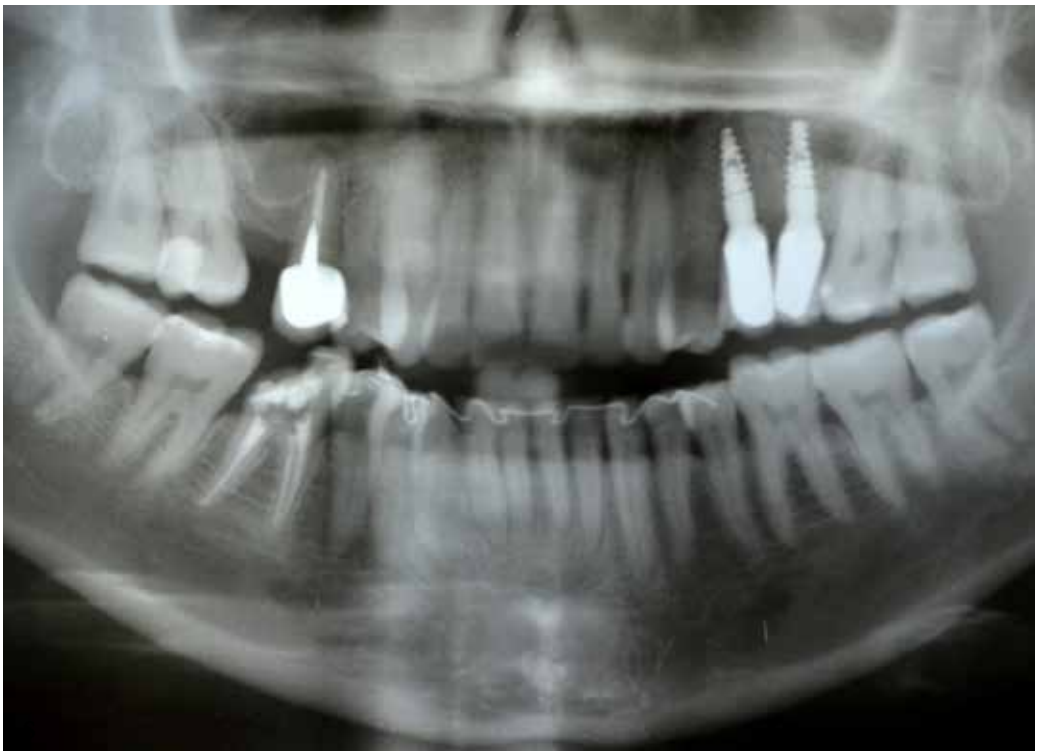


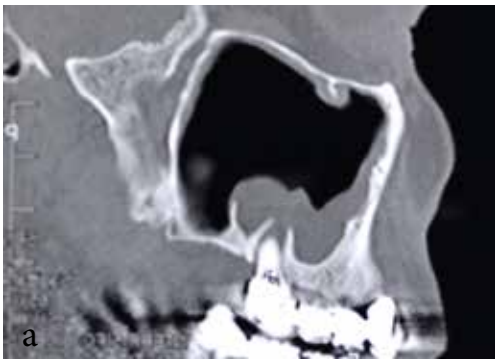
Fig. 5-29 (cont'd)

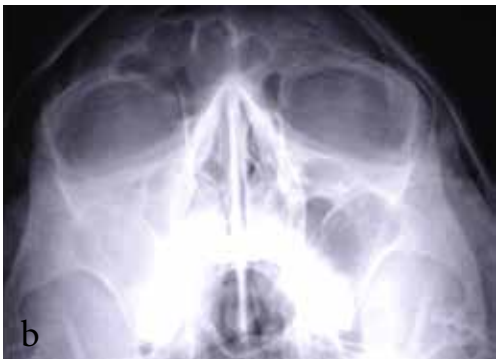
q Radiographic post-operative close-up view of implants immediately before healing abutment connections.

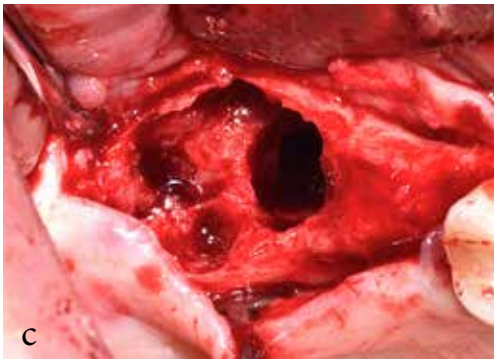
r Status of soft tissues around implants immediately before tacking the final impression.

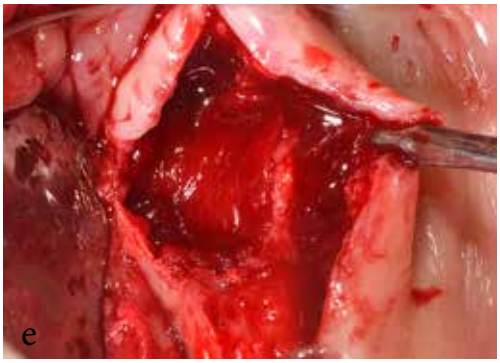
s Radiographic post-operative follow-up view.

Notes









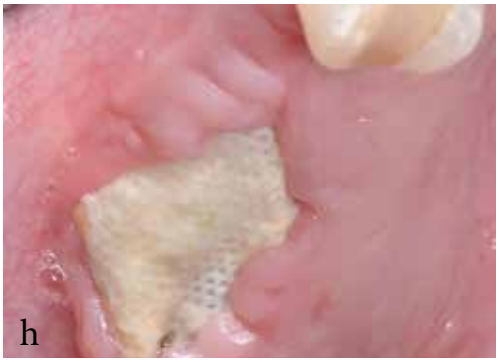


Fig. 5-30

a CBT of Chronic odontogenic sinusitis caused by tooth # 3.

b Radiographic frontal view of the compromised right sinus.

c After the extraction of tooth # 3 communication between the socket and the sinus is evident.

d A resorbable xenogenic collagen membrane is used to pull apart the sinus from the socket.

e The collagen membrane rebuilds the bottom of the socket.

f The socket is grafted with cortical allogenic bone and covered with a d-PTFE membrane.

g Some sutures stabilize the membrane in place.

h Clinical view of membrane on socket of teeth # 3 immediately before removal.

i Mature connective tissue has formed under it after a 4-week healing period.

Fig. 5-30 (cont'd)

j After eight weeks the wound is almost completely healed.

k CBT slice of the right sinus immediately before the sinus augmentation procedure(I).

l CBT slice of the right sinus immediately before the sinus augmentation procedure(I).

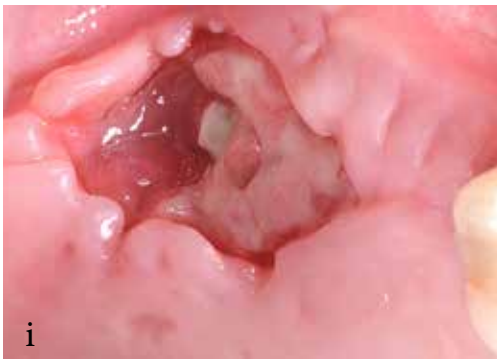
m CBT slice of the right sinus immediately before the sinus augmentation procedure(II).

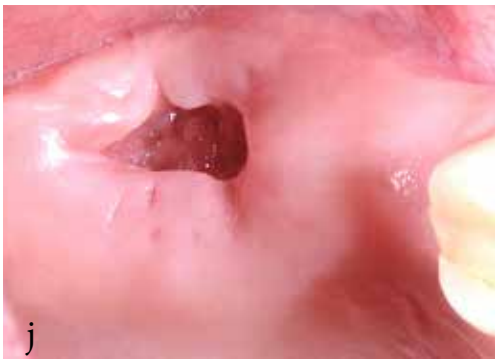
n CBT slice of the right sinus immediately before the sinus augmentation procedure(III).

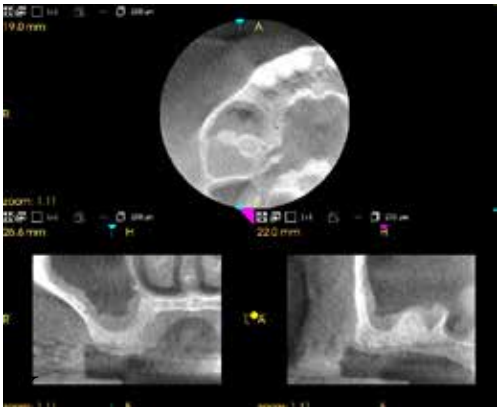
o Clinical pre-operative view.

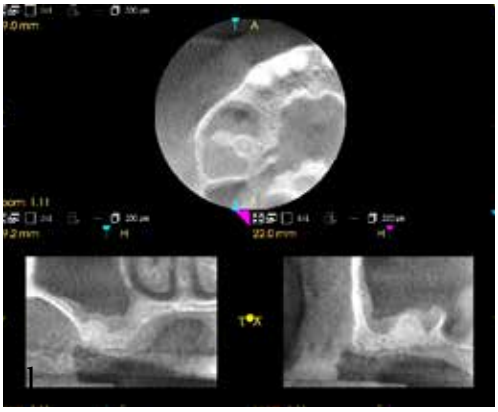
p Full-thickness flap refection.

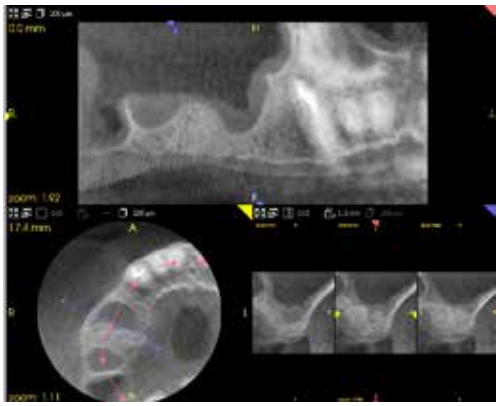
q Initial osteotomy. Notice the vertical oval shape.

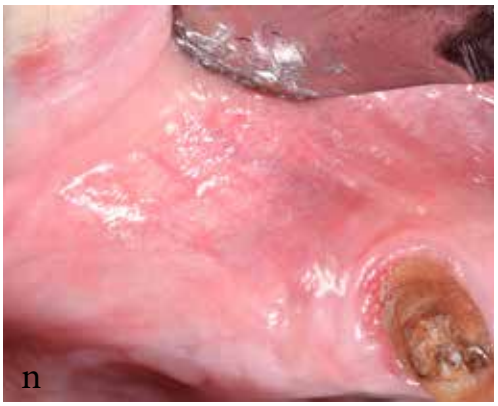


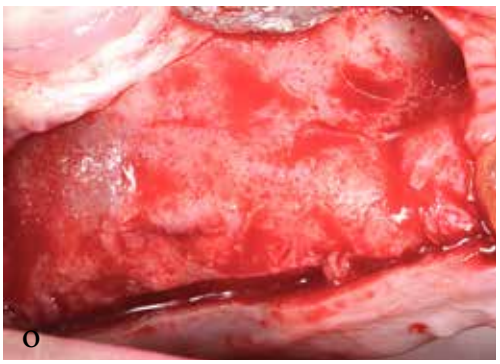


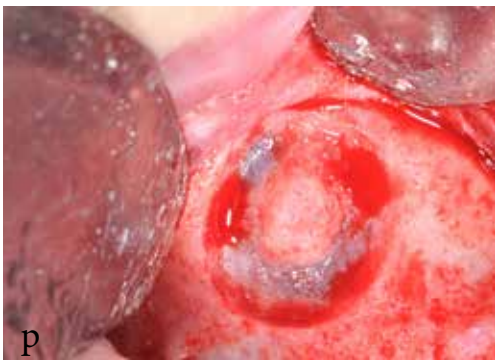


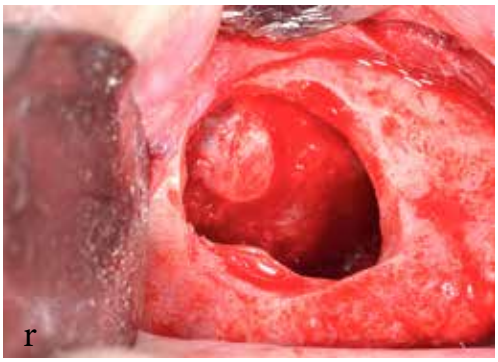


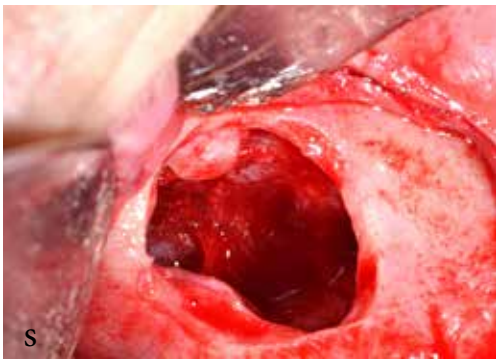


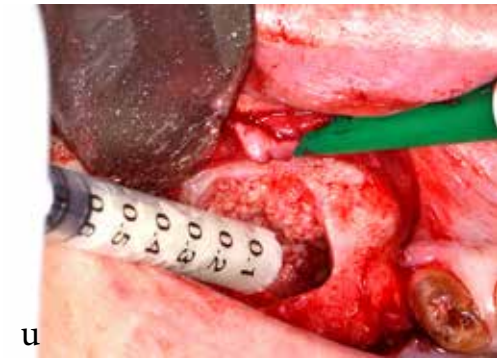


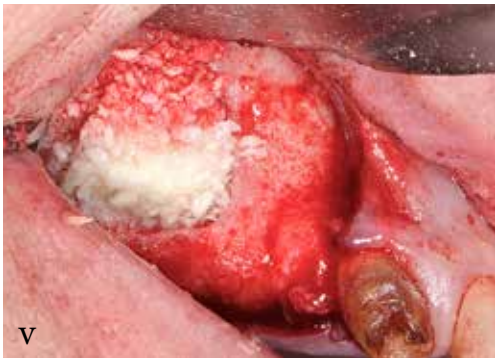


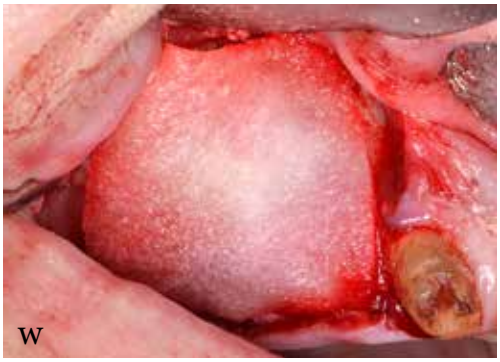












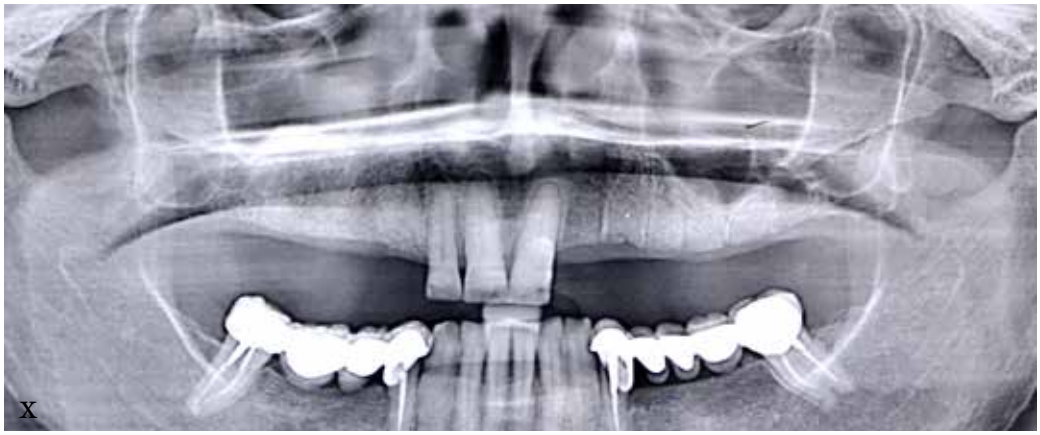


Fig. 5-30 (cont'd)

r Initial detachment of the membrane.

s Final detachment of the membrane.

t Bone is delivered into the sinus cavity using a tuberculin syringe.

u A large sinus may require several syringes in order to be fully filled.

v Antral cavity fully filled with cortical allogenic bone graft.

w Coverage of graft material with a resorbable xenogenic collagen membrane.

x Radiographic post-operative view of grafted sinus immediately before implant placement.

Fig. 5-30 (cont'd)

y Radiographic post-operative close-up view of grafted sinus immediately before implant placement.

z CBT slice of grafted sinus immediately before implant placement(I)

aa CBT slice of grafted sinus immediately before implant placement(II)

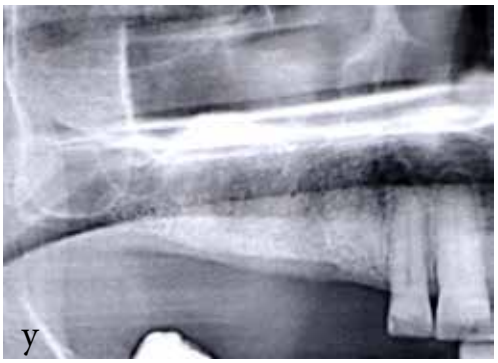
ab CBT slice of grafted sinus immediately before implant placement(III)

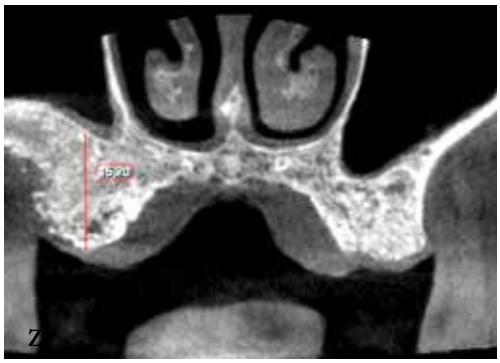
ac Clinical post-operative view of grafted sinus immediately before implant placement.

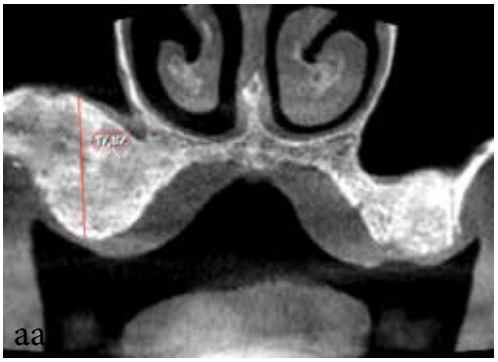
ad Full-thickness flap refection.

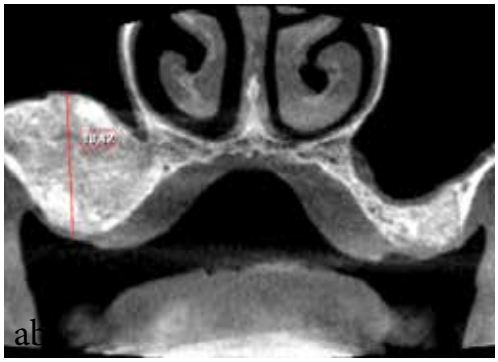
ae Implants in place.

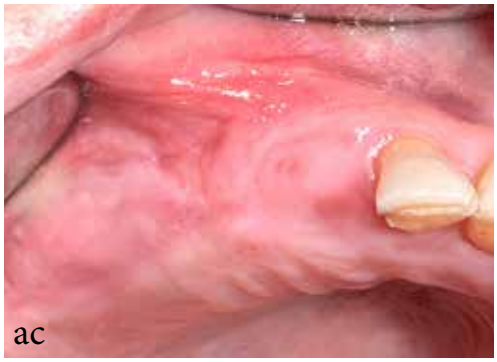
af A resorbable xenogenic collagen membrane is used to increase the amount of soft tissue around the implants.

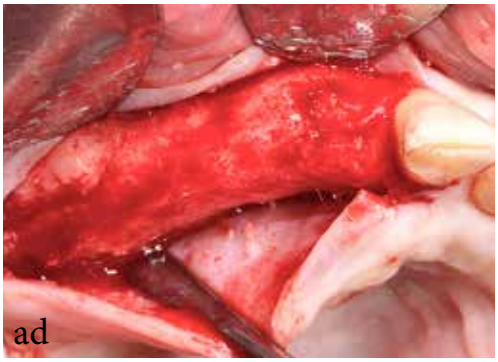


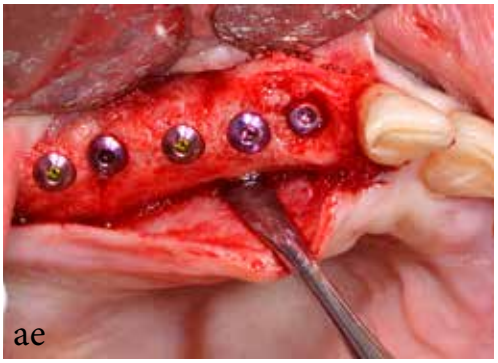


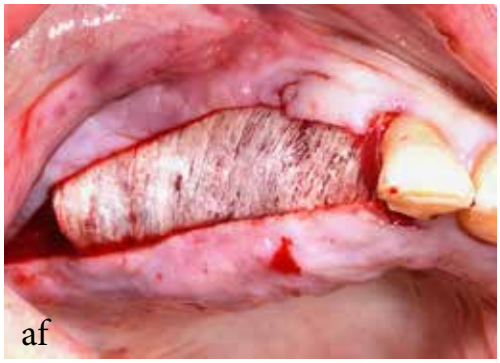


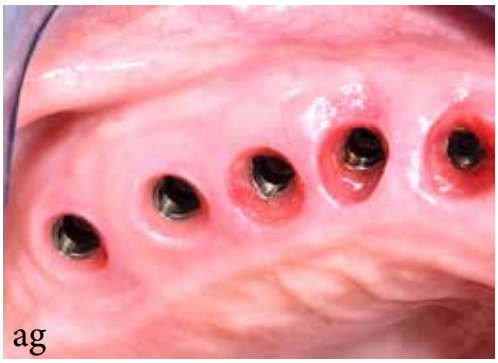


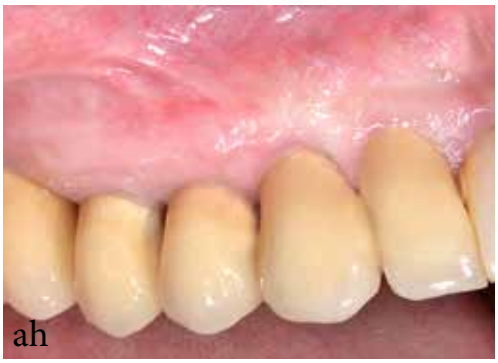


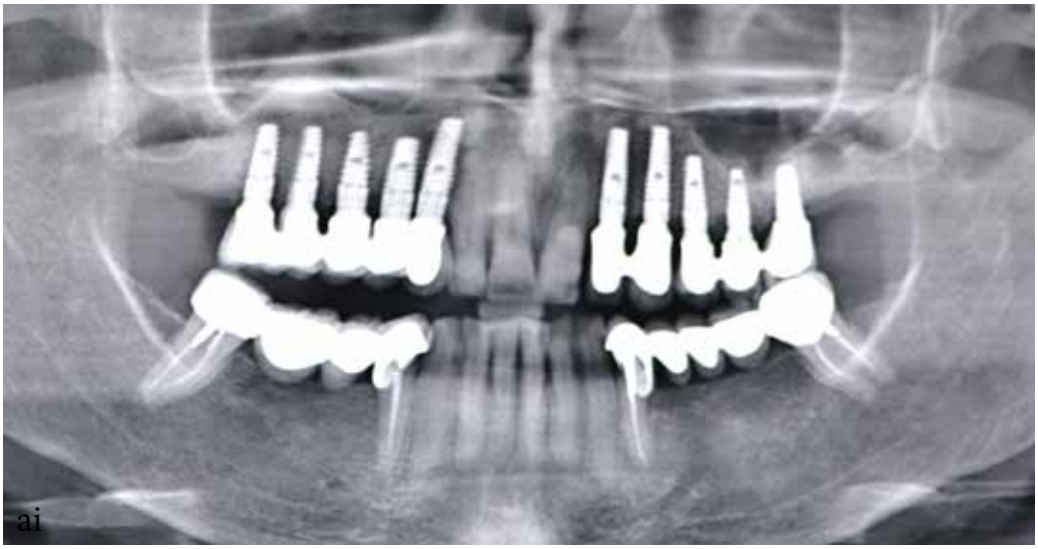


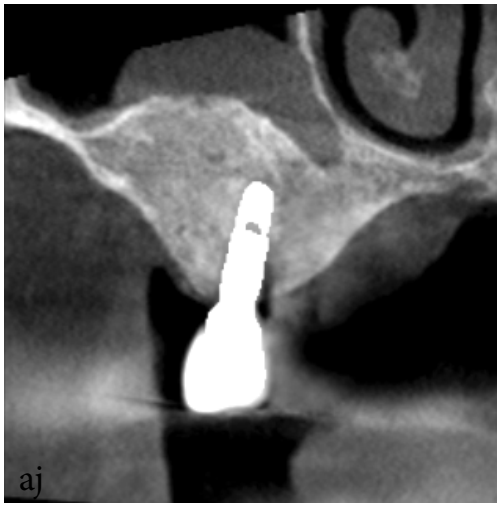












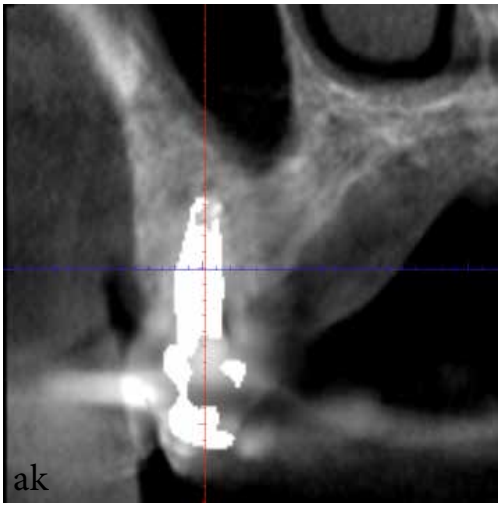


Fig. 5-30 (cont'd)

ag Status of soft tissues around implants immediately before tacking the final impression.

ah Clinical view of the cemented implant bridge.

ai Radiographic post-operative follow-up view.

aj CBT slice one year post-operative follow-up view(I)

ak CBT slice one year post-operative follow-up view(II)

Notes

CHAPTER

6 Surgery Technique for Crestal Approach

cedures described in this chapter.

Crestal Approach

The use of osteotomes eliminates the raising of a large flap to allow access to the lateral antral wall for surgical access. It is a less invasive procedure while allowing greater stability of implants.

With some similarities to the Lateral Wall technique, the Crestal Approach begins with a crestal incision followed by a full-thickness flap raised to expose the alveolar ridge. Osteotomes of increasing sizes are introduced to expand the alveolus. This improves bone density. A flat osteotome penetrates the alveolar bone to the same relative depth depending on bone thickness. The convex osteotome bores into the sinus cavity carefully avoiding perforation of the sinus membrane. Augmented bone is packed deep into the sinus site with the use of concave osteotome. The area is now stable enough for the dental implant.

Innovative Approach

An innovative approach to a crestal sinus lift procedure, the Crestal Approach Kit, combines elements of traditional drilling with a specially designed set of instruments with a specifically designed bur to cut the bone but whose tip is designed to prevent perforation of the Schneiderian membrane. This drill offers the clinician a more controlled, less traumatic, and more methodical approach for cutting the bone—instead of greenstick fracturing the sinus floor; the drill, in combination with specially designed curettes, also allows for a more effective separation of the membrane from

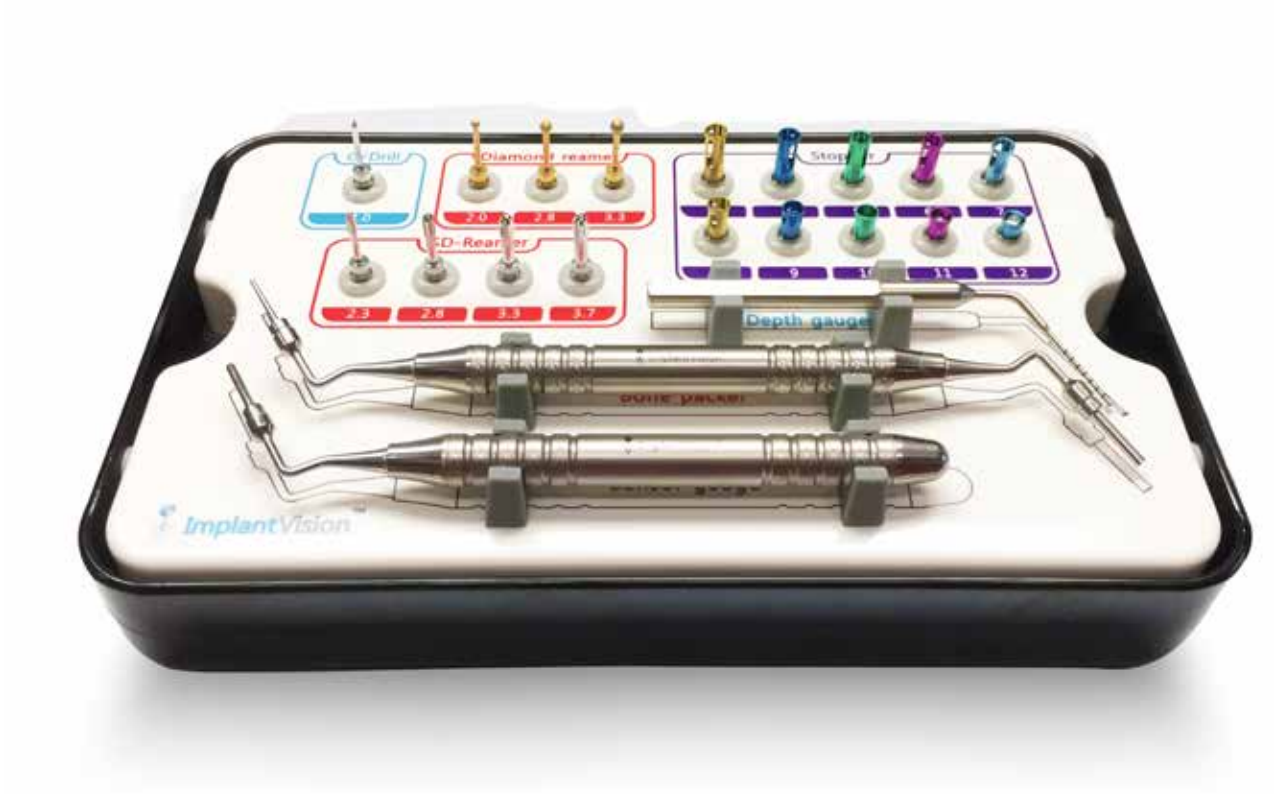


Fig. 6-1

Crestal Approach kit

the sinus floor prior to grafting. The Crestal Approach Technique is a surgical technique which is minimally invasive and allows for the placement of implants in the maxillary sinus region simultaneously.

The Crestal Approach Kit is comprised of:

1. The 2mm Guide Drill forms a guide hole making accurate point before using the reamer.
2. The Diamond Reamer is used to cleanse residual soft tissues after extraction and can also be used to be an initial guide when bone is thin.
3. The SD- Reamer is used to perforate the sinus wall. Its conical design helps safe membrane lifting at drilling.
4. The Sensor Gauge is used to check if sunus is perforated.
5. The Depth Gauge is used to measure the depth of the drilled hole.
6. The Bone Syringe is used to scoop ground bone and graft.
7. The Bone Packer is used to push bone material into sinus.
8. The Stopper helps over perforation.

Clinician should identify the location of the sinus and its anatomy. The usual protocol for an osteotome technique should be used to elevate the flap and to use a round bur to mark the de-

sired position of the implant. The site should be prepared with a 2 mm drill, and drilling should stop when the drill tip is 1 mm to 3 mm short of the sinus membrane. The prior step should be repeated using the 3.2 mm Start Drill. If desired, the clinician may use an intermediate sized drill prior to using the calibrated 3.2 mm drill.

The Crestal Approach Kit eliminates the need for osteotomes when fracturing the sinus floor, and this new surgical technique provides a much less traumatic experience for the patient and greatly minimizes the possibility of rupturing the sinus membrane.

Postoperative ConsideratÑns

Postoperative considerations for the maxillary sinus grafting procedure are similar to those for most oral surgery and sinus manipulation procedures. After the first week, a chlorhexidine mouthrinse should be used twice daily for 2 weeks to reduce the chance of infection. Blowing the nose, sucking liquid through a straw, and smoking cigarettes, all of which create negative pressure, should be avoided for at least 2 weeks after surgery. Coughing or sneezing should be done with an open mouth to relieve pressure. Pressure at the surgical site, ice, elevation of the head, and rest are also recommended. Analgesics should be used to control postoperative pain and discomfort. An anti-inflammatory medication and an antihistamine can also be used. Preoperative prophylactic antibiotic therapy, such as 500 mg Augmentin (GlaxoSmithKline, Research Triangle Park, NC) or a similar suitable antibiotic, should be used and continued postoperatively three times a day for 7 to 10 days. A nasal decongestant such as Sudafed (Warner Lambert, Morris Plains, NJ), 30 to 60 mg per day, should be prescribed, and Afrin (Schering-Plough, Kenilworth, NJ) nasal spray should be used as needed for nasal congestion.

Depending on the graft materials and the host osteogenic potential, 3 to 12 months should be allowed for the bone graft and implants to integrate before the prosthodontic phase begins. During this period, the patient can wear a conventional prosthesis that has been relined with a soft material. If an intraoral donor site has been used, it is usually well tolerated and recuperation normally takes 1 to 2 weeks.

Potential Postoperative ComplicatÑns

Possible complications that can occur after this procedure include sinus congestion, infection of the graft, poor wound healing, and the formation of insufficient quality or quantity of bone in the grafted site.[150,151] Sinus congestion and pain should be treated with decongestants and analgesics. If the graft becomes infected (which is rela-

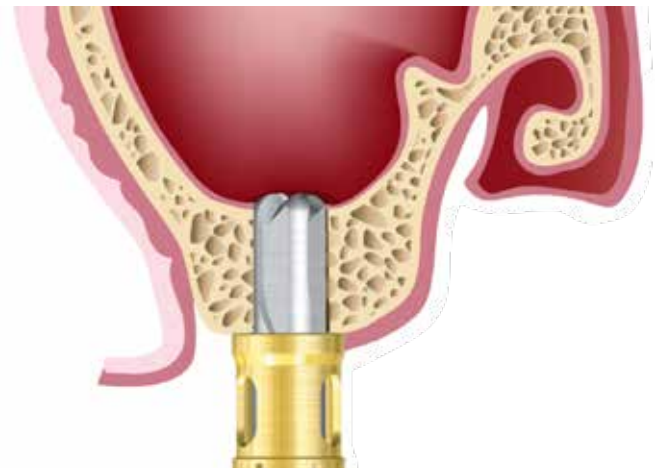


Fig. 6-2

The Stops are critical to the procedure as it prevents uncontrolled insertion of the drill into the membrane lining when the bone gives way.

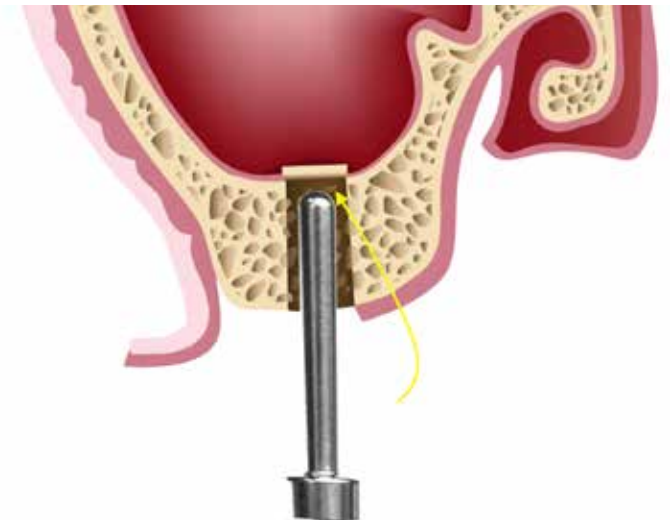


Fig. 6-3

After each 1mm additional depth, a nostril pressure test is used to make sure the sinus membrane has not been perforated.

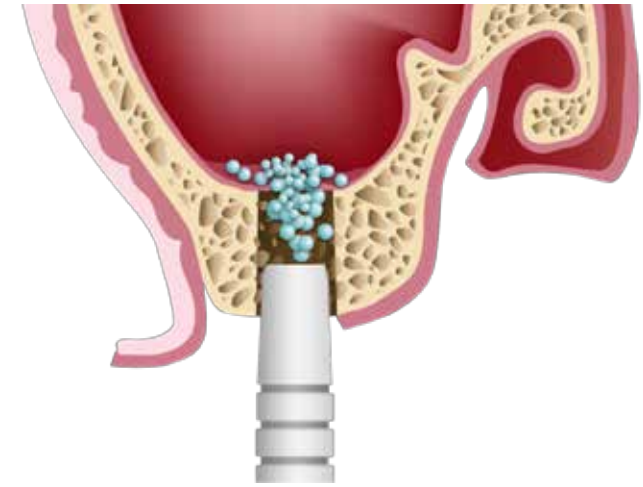


Fig. 6-4

Succeeding increases in diameter safe ended burs used.

tively uncommon), the graft material should be completely removed, the sinus membrane should be removed in a radical sinus antrectomy procedure, the area should be well irrigated, and antibiotic therapy should be prescribed. A nasal antrostomy procedure is generally not required. The sinus can be regrafted after the crestal soft tissue has healed and radiographs show the sinus to be clear.

If the blood supply to the tissue is interrupted or impeded, there may be poor wound healing and an early loss of the bone graft or implant. If the incision does not close properly, the remaining graft should be removed, the membrane inspected for perforations, and the sinus void irrigated. Appropriate antibiotics should be prescribed, and the wound should be allowed to heal by secondary intention.

If the graft fails to produce sufficient quality or quantity of new bone to sustain implants, the sinus void can be regrafted. After the lateral aspect of the sinus has been exposed, the graft material is removed, the surgical defect inspected, and the sinus regrafted with a different combination of materials.[1] Trauma to an implant during the healing process or pathologic loading from the restoration can also cause premature loss of implants. The loss of maxillary implants can create oro-antral openings that may require surgery for closure.[36]

Clinical Cases

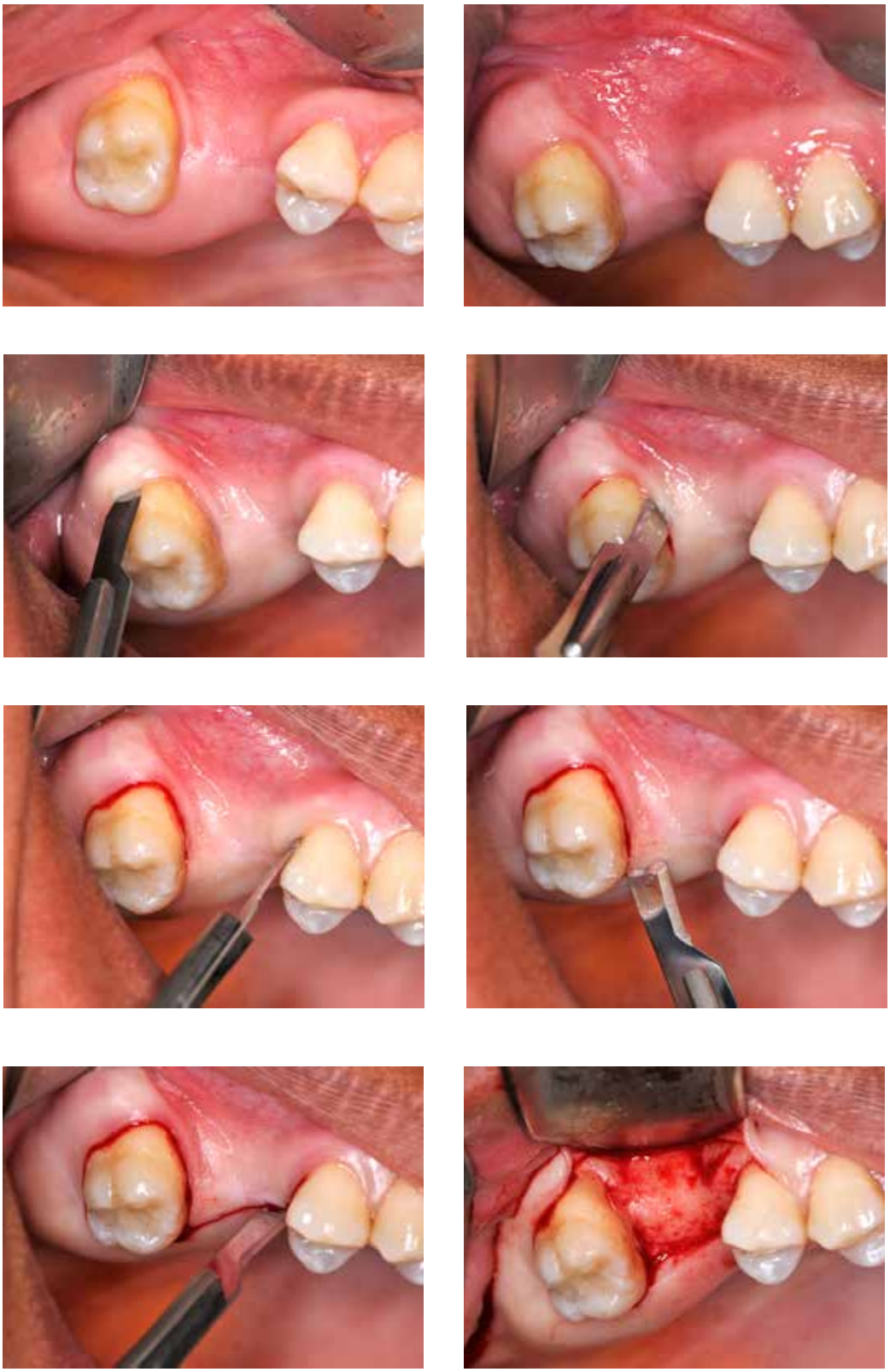
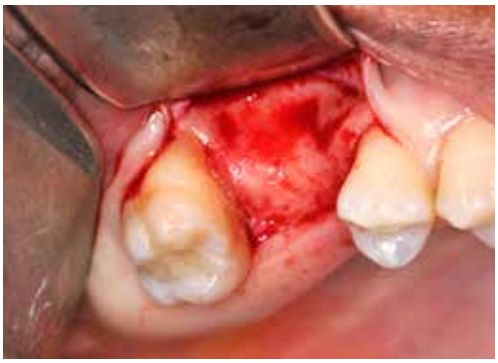
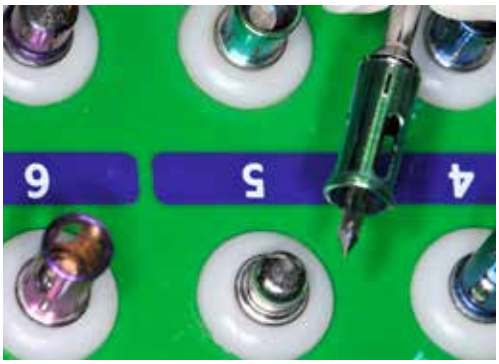


Fig. 6-5

Crestal approach utilizing the Implant Vision Crestal Kit

Fig. 6-5 (cont'd)







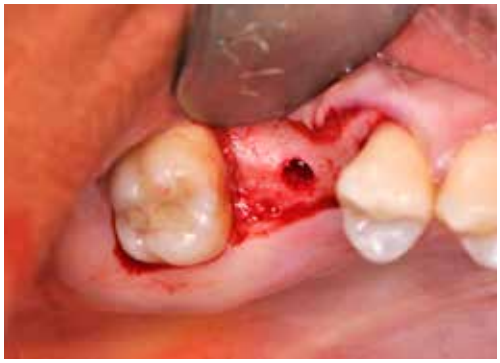
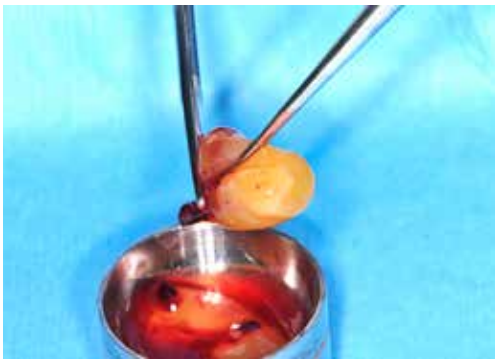
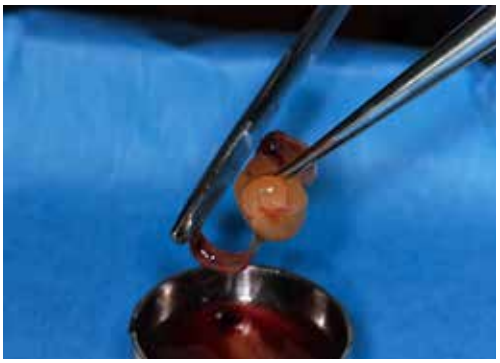


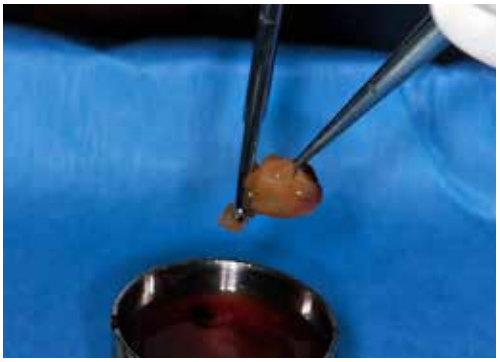


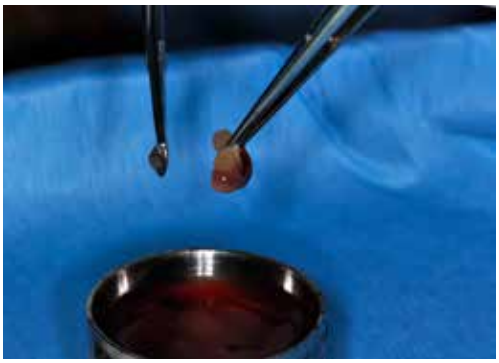

Fig. 6-5 (cont'd)

Fig. 6-5 (cont'd)











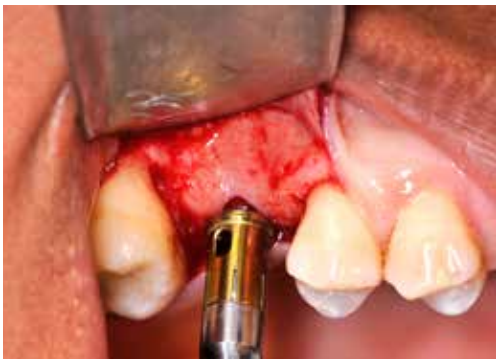
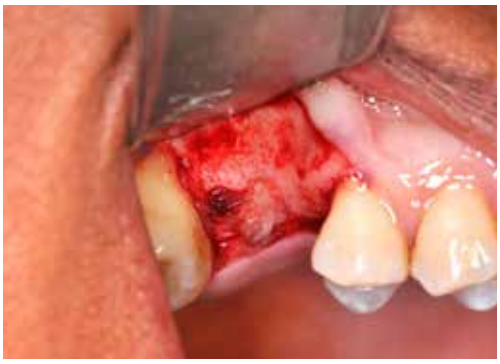



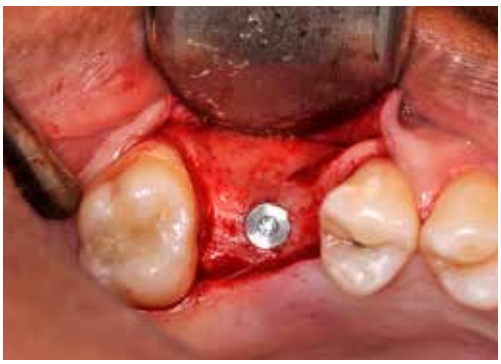
Fig. 6-5 (cont'd)

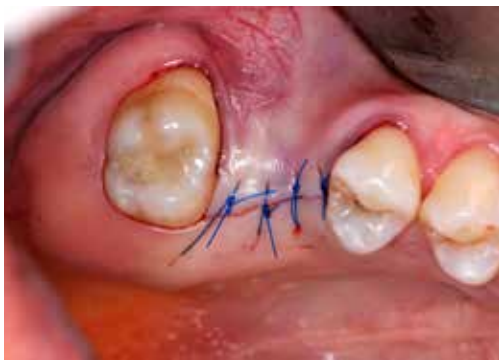
Fig. 6-5 (cont'd)


Surgical Drilling Kit
ImplantVision


ImplantVision


P8698
5-0
PP
Blue Monofilament
Polypropylene
Sterile
Nonabsorbable
Surgical Suture
18" (45cm)
P-3

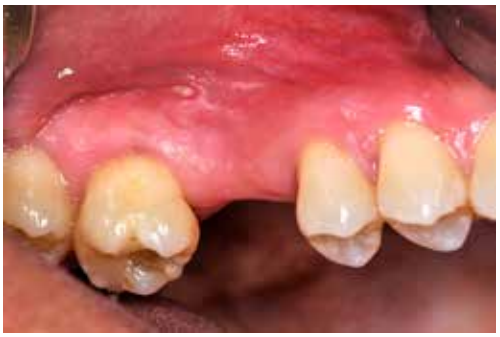


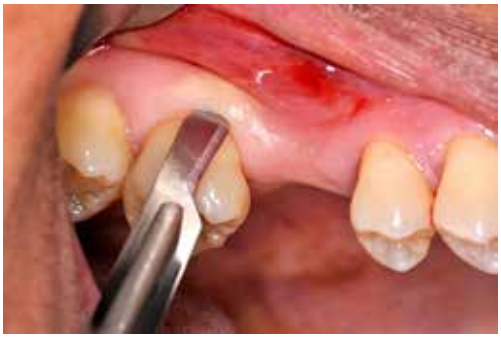


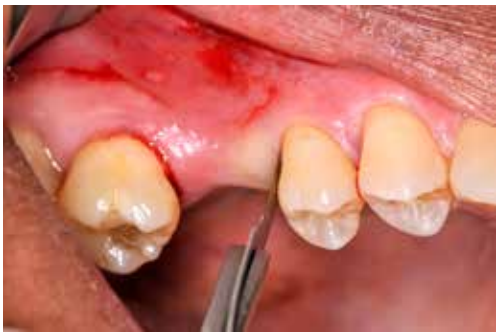
Notes

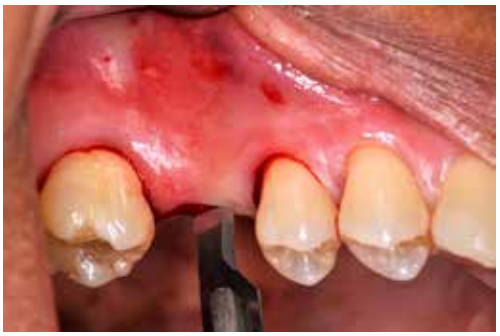
Fig. 6-6

Crestal Sinus lift utilizing the Implant Vision kit and PRP gel as a graft material with simultaneous implant placement.









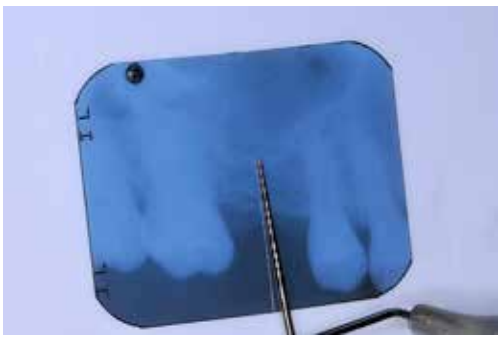




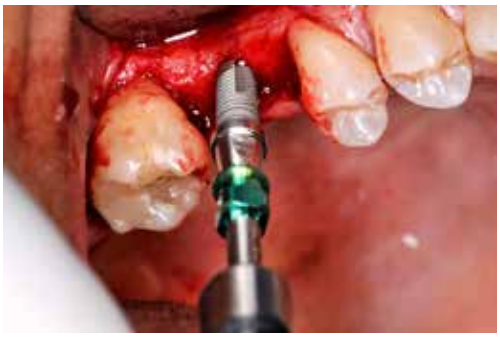




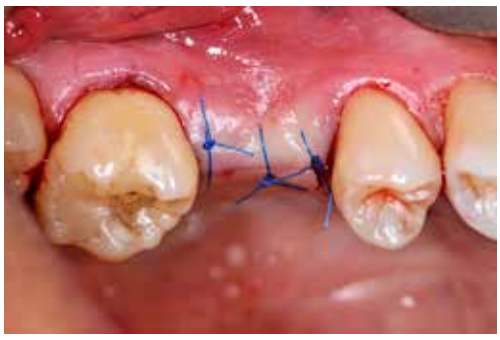

Fig. 6-6 (cont'd)

Fig. 6-6 (cont'd)







Notes

Notes

Figures 6-5 and 6-6 presents a crestal approach procedure.

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Notes

Arun K. Garg, DMD, is a nationally recognized dental educator and surgeon who for over 20 years, served as a full-time Professor of Surgery in the Division of Oral and Maxillofacial Surgery and as Director of Residency Training at the University of Miami Leonard M. Miller School of Medicine. Frequently awarded faculty member of the year by his residents, Dr. Garg is considered the world's preeminent authority on bone biology, bone harvesting and bone grafting for dental implant surgery and has written and published nine books and a dental implant marketing kit which have been translated in multiple languages and distributed worldwide. He has been a featured speaker at dozens of state, national and international dental association conventions and meetings including the American Academy of Periodontology, the American College of Oral and Maxillofacial Surgeons and the International Congress of Oral Implantologists. Dr. Garg is the recipient of numerous awards including outstanding educator by the ICOI and an award for best article published by the Implant Dentistry Journal. Dr. Garg earned his engineering and dental degrees from the University of Florida and completed his residency training at the University of Miami Jackson Memorial Hospital. He is also the founder of Implant Seminars, a leading dental continuing education company that offers a variety of class-based, hands-on, and live patient programs in the United States and abroad.

Gustavo Mugnolo, DDS, PhD, is a board certified Oral surgeon and Master in the International dental Implant association who graduated first in his class from Cordoba National University in Argentina in 1990. In 1992 he completed a residency program in Oral Surgery at the Deutsche clinic in Santiago (Chile) and started his long carrier as a well known Oral surgeon. In 1995 he obtained his Ph. D in Biomaterials at Cordoba National University (Argentina)

In 1998-1999 he completed a Fellowship in Oral Implantology at Jackson Memorial Hospital University of Miami School of medicine under the direct supervision of Professor Arun K. Garg, DMD.

With a private practice limited to oral surgery and Implant Dentistry, he is regarded a most prominent Oral Surgeon in Argentina with a subspecialty in Implants and related Bone Grafting.


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