Alveolar Bone Grafting

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74.1 Introduction

Attempts to graft the alveolus started in the early 1900. The rationale for the procedure however has changed over the period. From its use as a procedure for establishing continuity over a defect, it has evolved and made itself indispensable in both cleft-related orthodontics and orthognathic surgery. Over the years, the technique has evolved, and the materials used have also been constantly studied and improved upon. This chapter aims to elaborate on the morphology of the alveolar cleft, its implications on dentition as well as facial skeleton, and the various management strategies and evolving trends.

74.2 Normal Anatomy of Alveolus

The alveolar process is that part of the jaw that contains the tooth sockets and forms a bridge between the teeth and the basal bones. The alveolar process is present in both the maxilla and the mandible. The status of the alveolar process and its development depends on the status of the teeth; if the teeth are absent or lost in later life, it reduces in size, eventually disappearing completely.

74.2.1 Development of Alveolar Process (Figs. 72.1, 73.1, and 77.1)

The alveolar process begins to form in the end of the second month of fetal life. The maxilla and mandible develop a groove-like structure that opens toward the surface of the oral cavity. This groove contains the tooth germs, the dental nerves, and vessels. Gradually, bony septa begin to develop between adjacent tooth germs. Later the primitive mandibular canal is separated from the dental crypts through a horizontal plate of bone. The alveolar process remains fused to the body of the maxilla and mandible, and its formation is completed during tooth eruption.

74.2.2 Structure of Alveolar Process

There is no distinct boundary between the body of the maxilla or mandible and their corresponding alveolar processes. In conditions where the alveolus is not functionally related to teeth, it may be fused with and partly masked by bone.

Based on function, the alveolar process consists of two parts:

1. *Alveolar bone proper*: It consists of a thin lamella of bone which surrounds the root of the tooth and gives attachment to the periodontal membrane.
2. *Supporting bone*: It is the structure which surrounds the alveolar bone and gives support to the socket. The latter, in turn, consists of two parts.
   (i) The compact bone/cortical plate forming the vestibular and oral plates of the alveolar processes.
   (ii) The spongy bone between these plates and the alveolar bone proper.

The cortical plates are usually much thinner in the maxilla than in the mandible. They are thickest in the bicuspid and molar region of the mandible especially on the buccal side. In the maxilla, the outer cortical plate is perforated by many small openings through which blood and lymph vessels pass. In the mandible, the cortical bone of the alveolar process is dense and, occasionally, shows small foramina. In the region of the anterior teeth of both jaws, the supporting bone is, usually, very thin. No spongy bone is found here and the cortical plate is fused with the alveolar bone proper.

The interdental and interradicular septa contain the perforating canals of *Zuckerkandl and Hirschfeld*, which house

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the interdental and interradicular arteries, veins, lymph vessels, and nerves. The alveolar bone proper which forms the inner wall of the socket contains many openings which transmit branches of the interalveolar nerves and blood vessels into the periodontal membrane. It is named cribriform plate or lamina dura.

74.2.3 Functions of Alveolar Bone

The primary functions of the alveolar bone are highlighted in (Box 74.1).

74.3 Alveolar Anatomy in Cleft Patients

The alveolar cleft is usually represented either by a notch in the alveolus on the labial aspect or as a complete gap between the alveolar segments. In unilateral alveolar clefts, the cleft side of the maxilla (referred to as the lesser segment) is underdeveloped, causing abnormalities of the alveolus, as well as the lip, nose, and palate.

74.3.1 Abnormalities of the Alveolus and Dentition

The abnormalities of the alveolus and the dentition are projected in (Box 74.2).

74.3.2 Abnormalities of the Lip-nasal Complex

- The pyriform rim on the cleft side, when viewed sagittally, appears retrusive.
- The nasal floor is displaced inferiorly, and there is transverse constriction of the anterior bony nasal aperture.
- The nasal tip is asymmetrical.

Box 74.1 Primary Functions of the Alveolar Bone

1. Protection: Alveolar bone forms and protects the dental roots.
2. Attachment: It gives the attachment for periodontal ligament fibers, which are the principle fibers. These fibers which enter into the bone are called as Sharpey's fibers.
3. Support: It supports tooth roots on the facial and the palatal/lingual sides.
4. Shock absorber: It helps to absorb forces placed upon the tooth by disseminating the force to underlying basal bones.

Box 74.2 Abnormalities of the Alveolus and the Dentition

- There is medial collapse of the arch, producing dental crossbites (Fig. 74.1a).
- The position of the premaxilla may be altered with the arch being normal or rotated toward the non-cleft side. There is change in the position of the premaxilla.
- The central incisor is usually rotated toward the cleft side (Fig. 74.1b).
- The lateral incisor may be congenitally absent or hypoplastic or at times resemble a supernumerary tooth. It may also protrude through the nasal floor and lie within the cleft (Fig. 74.1c).
- The periodontal attachments of the central incisor and canine on the cleft side are poor and have high risk of future bone loss.

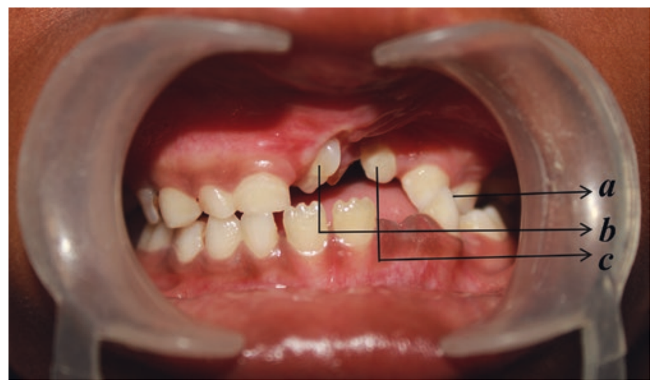

Fig. 74.1 Intraoral frontal picture demonstrating clinical features of cleft alveolus (left side). (Refer to Box 74.2 for description of a, b and c)

- The medial crus of the nasal cartilage is short, and the upper and lower lateral cartilages do not overlap. There is a mismatch in the level of lower lateral cartilages (Fig. 74.2a).
- The columella, caudal septum, and anterior nasal spine tend to deviate to the non-cleft side.
- The above factors result in lack of support for the external nose, especially around the alar base, which is displaced laterally, inferiorly, and posteriorly, widening the nasal aperture (Fig. 74.2b).
- The fibers of the orbicularis oris muscle do not run transversely and instead turn upward along the margins of the cleft, to terminate beneath the base of the columella medially and below the alar base and periosteum of the pyriform rim laterally. Due to the abnormal muscle attachment, there will be a bulge on the unrepaired cleft lip, distortion of the ala of the nose, and deflection of the nasal septum and anterior nasal spine.

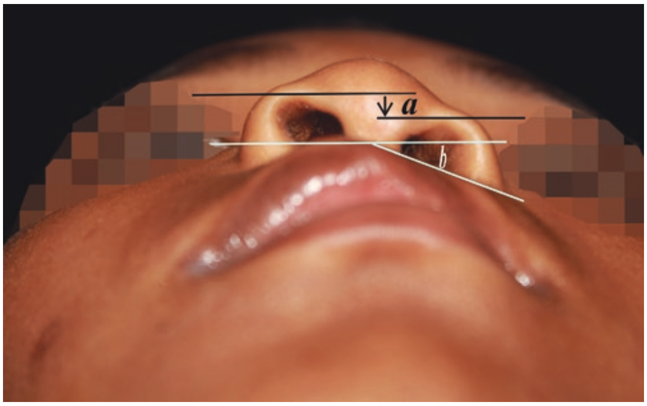

Fig. 74.2 Basal view picture demonstrating abnormalities of the lip-nasal complex (**a**) mismatch of the lower lateral cartilages and (**b**) widening of the nostril due to lack of support for the cleft side alar base

Box 74.3 Goals of Orthodontics in Alveolar Bone Grafting (ABG)

1. Alignment of arches in preparation for ABG.
2. Stabilize the arches.
3. Arch expansion to correct the transverse discrepancy.
4. Align the teeth.
5. Increase the cleft width in preparation to receive the graft.

74.4 Role of the Orthodontist in Patients with Alveolar Cleft (Box 74.3)

The objective of alveolar bone grafting (ABG) primarily involves restoring the structural and functional integrity of maxillary alveolar arch. This would further facilitate the eruption of the canine or lateral incisor into their respective position in the maxillary alveolar arch. The further employment of orthodontic treatment would help in stabilizing the arches and achieving proper alignment of misaligned teeth, The aim of orthodontics in ABG are highlighted in Box 74.3.

The orthodontist must be involved at all stages of dental development, namely, infancy, primary, mixed dentitions, and the permanent dentition stages.

74.4.1 Infancy

1. Pre-surgical orthopedics can be done with the use of appliances such as Latham's appliance, etc. It consists of a pin-retained device that is inserted into the palate with acrylic extensions onto the alveolar ridges. Further a screw mechanism is then used to manipulate the segments as desired.
2. Primary bone grafting is also an option, which is done in some cases, as it was believed that defect, which when corrected earlier, would allow normal development and function. However, it remains controversial, as there are no important benefits compared to secondary bone grafting done. In addition, scarring can cause deleterious effects and retard growth.
3. Gingivoperioplasty can also be done to improve the closure. It involves creation of a mucoperiosteal bridge across alveolar cleft region, thus creating a subperiosteal tunnel. This in turn facilitates bone generation.

   In case of untreated clefts, the maxillary development was found to be normal. Which indicates that early lip repair may affect maxillary growth.
4. In case of a bilateral cleft repair, posterior alveolar segments behind the premaxilla are collapsed leading to a protruded and superiorly positioned premaxilla.
5. Orthodontist's role would be to reposition the maxilla and expand the collapsed alveolar segments.

   Jackscrew and spring-loaded appliance are some of the orthopedic appliances used. However, the effect of these appliances are still controversial.

74.4.2 Primary Dentition

1. In a primary dentition, the orthodontist has no role to play unless the children have crossbites.
2. Routine dental screening is advised to detect any caries.

74.4.3 Mixed Dentition

1. Standard records for orthodontic diagnosis are procured for the patient. Some of them being OPG, IOPA, and occlusal radiographs.
2. Missing teeth, supernumerary teeth, and bone requirement are assessed with these radiographs.
3. Presence of posterior crossbite, malaligned upper incisors, and bone defects at the cleft area are documented.
4. Bone grafting should be done prior to any orthodontic treatment, which is to prevent root exposure or periodontal defects.
5. Arch expansion done should be limited if the patient is supposed to undergo orthognathic surgery later.
6. The expansion is usually limited by the zygomatic buttress and scar tissue present.
7. The direction of the expansion, its extent, the presence or absence of teeth, the resistance of tissue (which can

be high in scarring), surgical access to cleft area, and compliance of the patient are factors that determine the selection of appliance.

8. Spring appliances offer lighter forces with quad helix providing better control in the expansion.
9. Any fistulae that are present in the patient should be corrected during bone grafting.
10. In case of bilateral cleft, the mobile premaxilla is stabilized by grafting, and orthodontic treatment is started only after the bony union is complete, which may be a range between 2 and 6 months.
11. Orthopedic appliances like headgears can be given to patients with mild maxillary deficiencies.
12. Distraction osteogenesis or orthognathic surgery should be chosen depending on the patient's growth status (refer Chap. 69 on maxillary orthognathic surgeries, Chap. 75 on cleft maxillary hypoplasia and Chap. 87 on distraction osteogenesis).

74.4.4 Permanent Dentition

1. Fresh set of diagnostic records are obtained.
2. Most common problems which are seen are missing or malformed teeth.
3. Sometimes teeth may be present but compromised. Most often it is the lateral incisor. One must decide whether this has to be treated with canine substitution or prosthetic replacement.
4. In cases where there is (i) deviation of the dental midline toward the non-cleft side, with the canine erupted mesially with favorable root position, or (ii) the canine is small and wide with both premolars present on the cleft side, and the molar and canine relationships on same side are *class* II, the right choice of treatment would be canine substitution. It involves extraction of the malformed lateral incisor with poor periodontal support, followed by facilitating the eruption of canine in the place of lateral incisor.
5. In cases in which both the maxillary canine and the first molar have a class I relationship, or the canine is positioned with the crown mesially and root distally, with a shift of the maxillary midline to the cleft side, prosthetic replacement is ideal. Adequate space should be planned to accommodate the prosthesis.
6. Comprehensive orthodontic treatment starts almost a year or 2 prior to surgery.
7. Dental decompensation for cleft maxillary osteotomy surgery must be planned and executed. Surgical preparation should include wire placements, retentive hooks for IMF, and plans for post-surgical retention.
8. If relapse is noticed post-surgically, it is immediately addressed with class III elastics or a reverse pull headgear.

74.5 Alveolar Bone Grafting Procedure

74.5.1 History [1]

Attempts to graft the alveolus started in the early 1900s. In the beginning, the goal was to prevent collapse of the alveolar ridge. Therefore, it was done during infancy. In 1970, reconstructive surgeons like Boyne [2, 3] stated that the ideal age for grafting the cleft was between 9 and 11 years. This was done to allow eruption of the canine.

74.5.2 Classification

Alveolar bone grafting procedures are classified into four types based on the age and timing of the procedure:

- *Primary*—This is performed in infancy, with the patient being below 2 years of age. This is done following lip repair but before the palate is repaired.
- *Early secondary*—This is done between 2 and 5 years of age, prior to the eruption of incisors.
- *Secondary*—Performed between 8 and 11 years of age, prior to eruption of the maxillary permanent canine.
- *Late secondary*—Performed above 12 years of age, after the canine has erupted.

The advantages and disadvantages of the various methods are highlighted in Table 74.1.

74.5.3 Materials Used in Alveolar Bone Grafting

A variety of materials have been used in grafting in secondary cleft deformities.

These include autogenous, allogenic, or alloplastic materials.

The success rate differs for each type, but fresh autologous cancellous bone is considered to be superior because it allows cells that are immune-compatible and integrate fully into the maxilla and trigger osteogenesis. In addition, it is the only bone source which possesses all the properties that promote bone formation—osteogenesis, osteo-conduction, and osteo-induction.

74.5.3.1 Bone Grafts

- Cortical:

  Cortical bone refers to the compact outer part of the bone. This is generally less vascular, and so establishment of nutritional supply to cortical cells is a slow pro-

Table 74.1 Comparison of advantages and disadvantages of different ABG techniques

Procedure	Advantage	Disadvantage
Primary grafting	Limited dissection. Reduced maxillary growth discrepancy	Alveolar segments have to be aligned orthopedically. Requires additional surgeries. Reduced success rates [4]
Early secondary grafting	Possibly could facilitate eruption of lateral incisor as well	Not accepted widely in literature [4]
Secondary grafting	Minimal influence in maxillary growth as most of the maxillary growth is completed by 6–7 years [4]. Sufficient quantity of bone at donor site is available. Better patient cooperation. Orthodontic treatment acceptance is good. Allows eruption of permanent teeth through the graft, thus maintaining good periodontal health	Earlier intervention could result in eruption of lateral incisors as well
Late secondary grafting	No significant advantage. Mandibular symphysis could be considered as good donor site as the chances of damaging unerupted teeth are less	Less success rate. Loss of osseous support to teeth adjacent to cleft. Less chances of salvaging lateral incisor. Delay in orthodontic correction of underlying deformity

cess. Therefore, this graft generally resorbs and is replaced by invasion of bone cells originating from the recipient site. The rate of metabolic turnover and cortical bone remodeling is much slower than in cancellous bone. Therefore, keeping the tooth-bearing function in mind, cortical grafts may not be feasible for the alveolar process.

- Cancellous:
  Cancellous bone refers to the softer trabecular bone that is more vascular. This allows better ingrowth from the recipient site. The formation of new bone starts at the surface of the existing cancellous bone. Cancellous bone theoretically heals by osteogenesis, followed by bone resorption and deposition. This graft is harvested as a particulate form, so it may be difficult to stabilize it in the recipient site.
- Cortico-cancellous:
  A combination of the two produces good results and enables good vascularization to help incorporate bone with surrounding structures. It also adds good mechanical strength.

74.5.3.2 Autogenous Materials

The following sites are commonly used as sources for autogenous material used in alveolar bone grafting:

1. Cranium [5]
   - The cranium, or calvarial bone, is a source of both cortical and cancellous bone.
   - This site is associated with low morbidity and minimum postoperative pain.
   - Scar will be unseen within the hair with early discharge and good prognosis.
   - It has poor outcomes as compared to iliac crest bone.
2. Iliac Crest [6]
   - It has huge quantity of cancellous bone which aid osteogenesis. The process of condensing bone chips into the defect increases the reliability of this bone.
   - Bone from this region may be harvested using a trephine or through an open approach.
   - Approach needs to be planned well as it may leave an unacceptable scar.
   - The main disadvantage of using iliac crest is postoperative pain, which may require extended hospitalization, which can be surmounted by regional anesthetic techniques for post-surgical pain control.
   - This is the most preferred donor site and is used by 87% of European surgeons and 83% of North American surgeons performing ABGs [6].
3. Mandibular Symphysis [7]
   - Bone provided is more cortical and is limited compared to the ilium.
   - Damage to the adjacent teeth and mental nerve has been reported.
   - It is used by 4% of surgeons in Europe [7].
4. Tibia [8]
   - It has sufficient bone which is quick to harvest.
   - There is minimal scarring, and patient may be mobilized early but is restricted from sports for 3 weeks.
   - In children where the tibia is usually small, there is a possibility of damage to the epiphyseal cartilage.
   - Used by 3% of European and 2% of North American surgeons [8].
5. Rib [9]
   - This is rarely used, as it provides limited amount of bone.
   - Postoperative risk of chest infections and prolonged discomfort may be present.
   - Esthetically identical scar to other sources.
   - 0.5% of European and 3% of North American surgeons use this method [9].
6. Femur
   - Bone may also be harvested from the intermedullary canal of the femur, but it carries the risk of high morbidity.

74.5.3.3 Alloplastic Materials

Alloplastic materials that have been used for ABG include rhBMP-2 (recombinant human bone morphogenetic protein), undecalicified freeze-dried bone, TEOM (tissue-engineered osteogenic material), and bioglass.

1. rhBMP-2
   - This is recombinant bone morphogenic protein, with superior bone quality reported in BMP-2 group [10].
   - Studies have shown that this material, when used for ABG, had high chances of successful grafting as is considered very effective in situations involving a larger bony defect, and does not demonstrate any detrimental effect on neighboring anatomical structures and no evidences of ectopic bone formation [11].
2. TEOM
   - This material contains MSC (mesenchymal stem cells), PRP (platelet-rich plasma), human thrombin, and mixed air.
   - Available in a gel form.
   - Claimed rate of success is about 70%.
3. Bioactive Glasses
   - This commercially available material is made up of silicone dioxide, sodium dioxide, calcium oxide, and phosphorus pentoxide.
   - It binds both to the soft tissue and bone.
   - Designed to engender surface reaction, which leads to osseointegration.

74.5.3.4 Allogenic Materials

These materials are comparable to autogenous materials and allow for eruption of teeth while avoiding donor site morbidity. However, they do not have osteogenic potential, which causes delayed graft incorporation.

These materials include:

- Undecalcified freeze-dried bone.
- Allograft CTBA [Cells and Tissuebank Austria].
- Osteograft.
- Maxgraft.

Most of the abovementioned products involve bone obtained from genetically dissimilar individuals. These allogenic bone particles are subjected to various processes to ensure the allogenic graft material is devoid of any microbial contamination however retaining the organic matrix and the inorganic components. They are available in various particle sizes or as block grafts or can even be milled for specific patients using CAD CAM technology.

Box 74.4 Goals of ABG

- To allow closure of the oronasal fistula.
- To provide tension-free, watertight closure to retain the graft and establish soft tissue continuity.
- To pack adequate volume of graft in the defect and restore bony continuity.
- Aid in the eruption and alignment of teeth.
- Add stability to the maxilla as a single unit while planning for orthognathic surgery.

74.5.4 Technique for Alveolar Bone Grafting

The technique of alveolar bone grafting must be performed with the following goals in mind (Box 74.4).

Alveolar bone grafting procedure is performed under general anesthesia. It can be performed comfortably using both naso-tracheal and oro-tracheal intubation. When iliac crest is the chosen donor site, a two-team approach can be followed simultaneously. The surgical sequence for unilateral ABG (Figs. 74.3a–f and 74.4a–f) and bilateral ABG (Fig. 74.5) are detailed below.

Surgery in the oral cavity is begun with infiltration of local anesthesia containing adrenaline to assist hemostasis. It has to be borne in mind that the reconstruction of cleft alveolus involves neat and precise development of labial/palatal/nasal layers and creating of a pocket for placement of graft, as this will ensure creation of structural and functional integrity of the alveolar arch. A fine needle gauge is used to probe the bony edges of the cleft in order to identify the site of the first incisions (Fig. 74.5b). The initial incision must be made through the mucosa lying over the cleft and must pass down to the bony margins (Fig. 74.3a, b). Try to preserve the soft tissue on the labial and palatal sides. Adequate (and sometimes excess) tissue is usually present within the oronasal fistula, which may be sacrificed after planning for the oral layer closure. In the region of the pyriform aperture, there is no bony margin. Hence, at this site the soft tissue is divided to provide a layer for the superior most extent of the nasal closure. A similar kind of division of the mucosa is necessary on the palatal side too (Fig. 74.3c).

Next, incisions are made around the cervical region of the teeth on the labial aspect of the alveolus. The incisions should extend several teeth posteriorly from the cleft with the exact distance determined by the width of the cleft. A full-thickness mucoperiosteal dissection should be begun to raise a large advancement flap. A similar procedure is carried out on the palate, where incisions are made around the neck of the teeth followed by full-thickness mucoperiosteal dissection. As an alternative oblique sliding flaps can also be raised (Fig. 74.3a, b). As these dissections are proceeding,

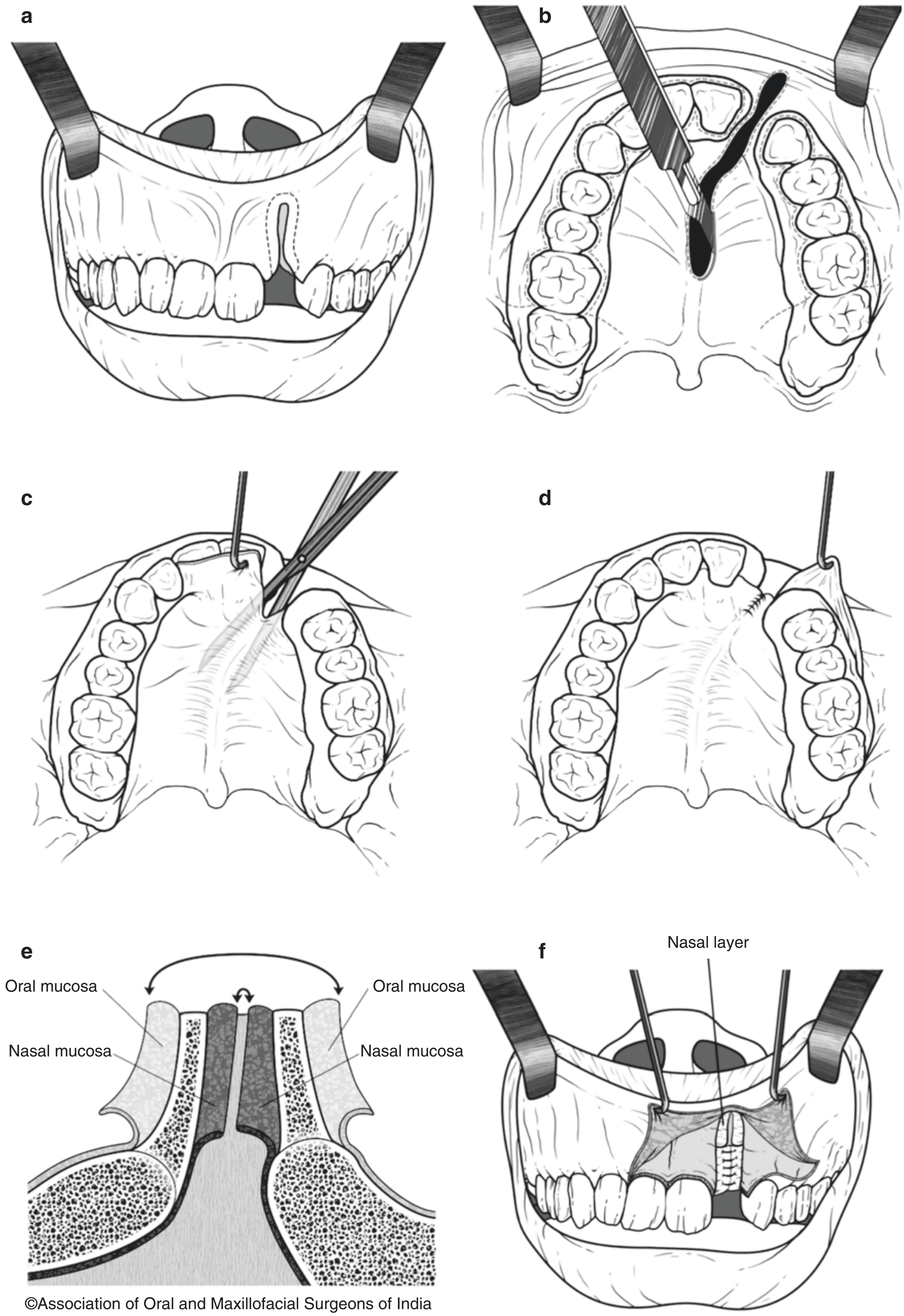

Fig. 74.3 (**a**–**f**) (**a** and **b**) Incisions around the cleft margin and for developing oblique sliding flaps (dashed lines), (**c**) Palatal flaps are developed sharply with scissors. This also separates the nasal mucosa from the palatal tissue. (**d**) Palatal closure. This can be done before or after the nasal mucosa is closed. (**e**) Depiction of the nasal mucosal flap along with the closure of the oral mucosa. (**f**) Nasal mucosal flaps are reflected from the bony walls of the cleft. The palatal flap facilitates packing and protects the palatal closure [4]

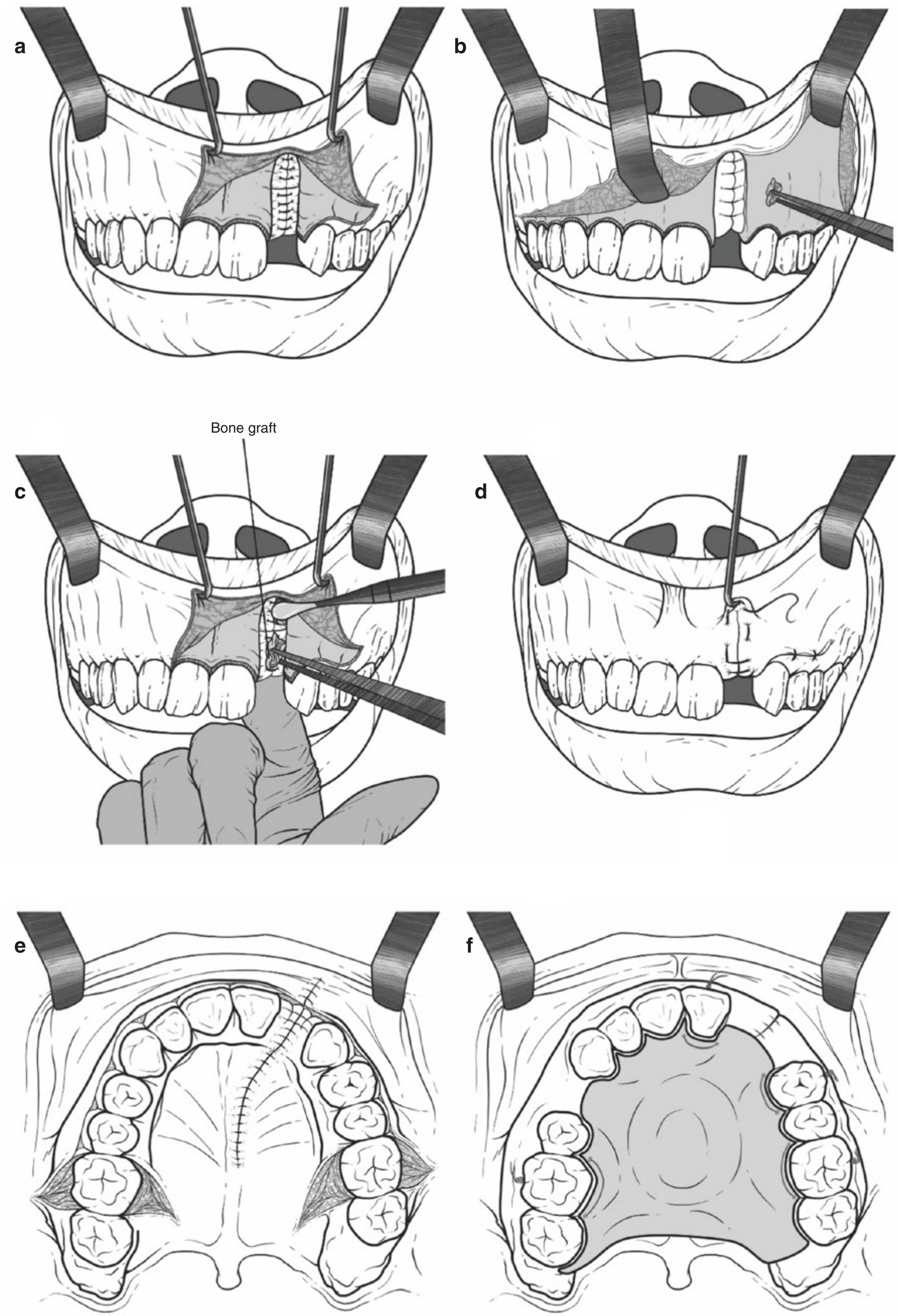

Fig. 74.4 (**a**–**f**). (**a**) Nasal flaps are approximated with sutures burying the knots when possible. (**b**) The closure of the nasal mucosa and the introduction of the bone graft to the alveolar defect. (**c**) Bone is packed into the defect with a periosteal elevator or orthodontic band pusher. Digital pressure against the palatal flap facilitates packing and protects the palatal closure [4]. (**d**) Closure of the labial oblique sliding flap. (**e**) Final mucosal closure of the labial and palatal oblique sliding flaps. (**f**) A palatal splint placed over the closure area to prevent formation of a hematoma and stabilize the bone graft

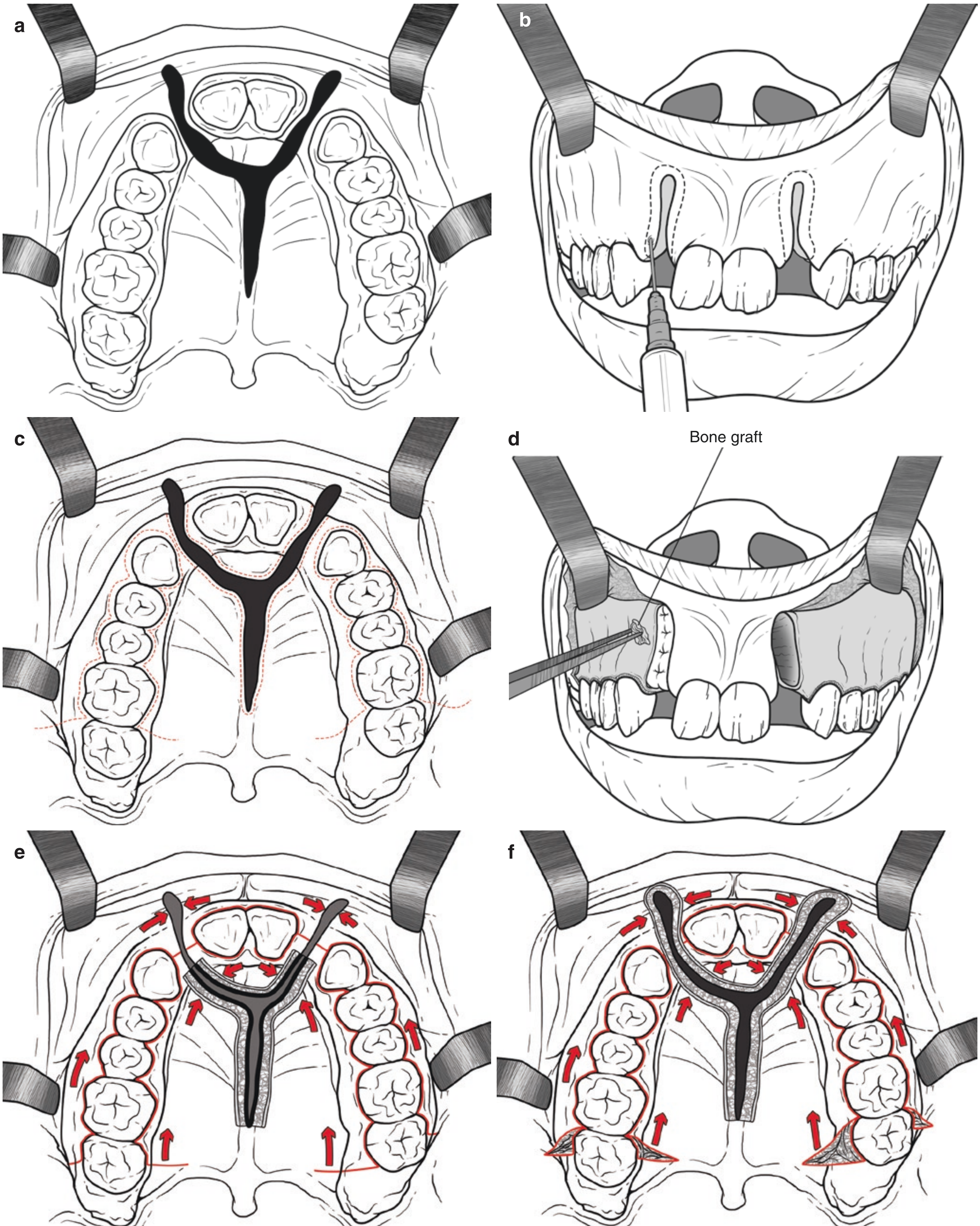

Fig. 74.5 (**a**–**i**) (**a**) A bilateral alveolar cleft palate. (**b**) Needle palpation of the bony edges of the alveolar cleft while injecting local anesthesia. (**c**) The incision line (dashed line). (**d**) Elevation of the nasal mucosa on the left and closure of the nasal mucosa on the right. Placement of the bone graft. (**e**, **f**) Palatal depiction of the movement of the adjacent mucosa in the oblique sliding flap technique. (**g**) Mucosal closure in a bilateral alveolar cleft. (**h** and **i**) Final closure of the bilateral alveolar cleft repair using an oblique sliding flap technique

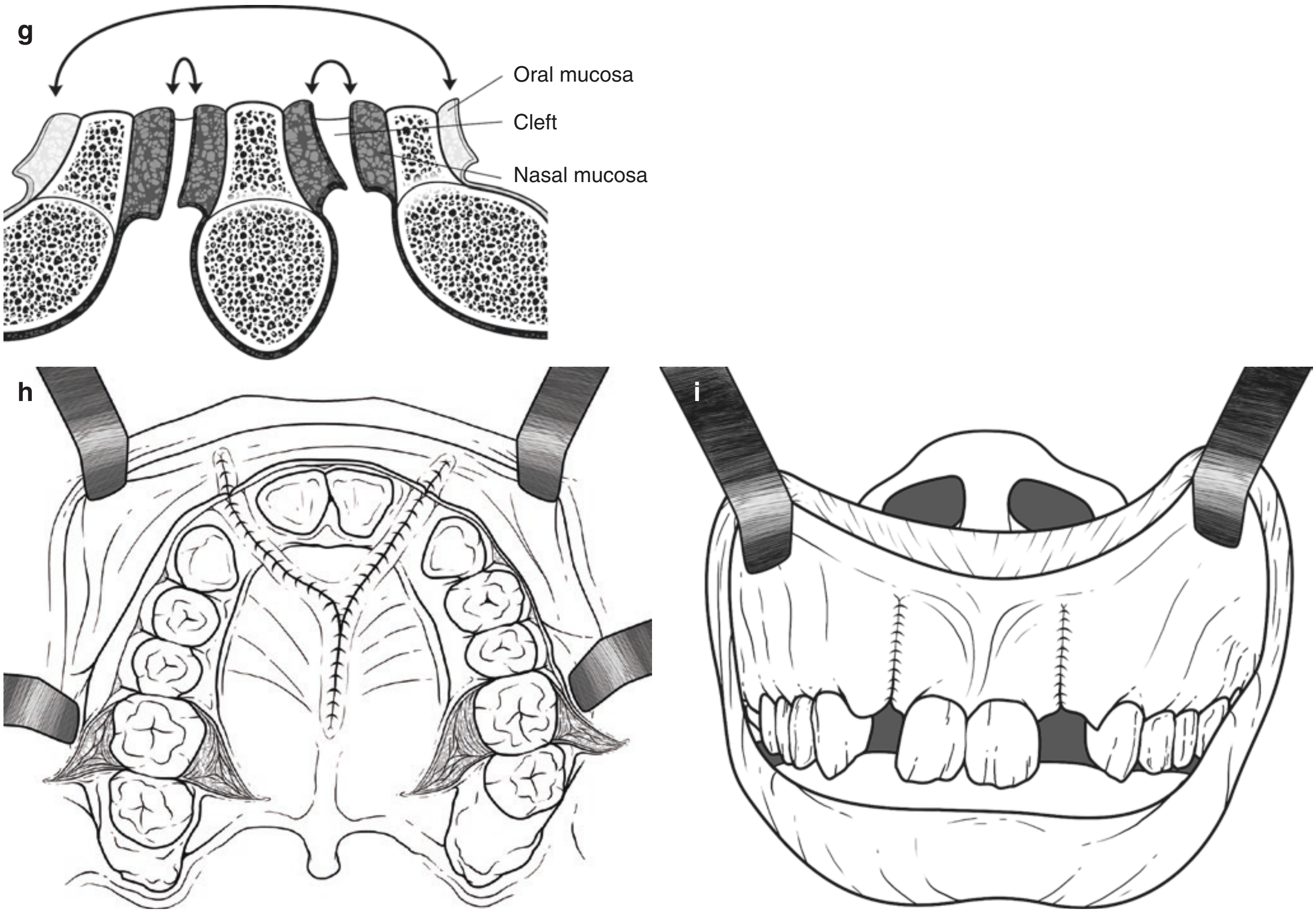

Fig. 74.5 (continued)

Fig. 74.6 Pre-operative intra oral picture demonstrating collapsed maxillary arches with hidden oro-nasal fistula

Fig. 74.7 Pre-operative intra-oral maxillary arch view of the same patient in Fig. 74.6, providing good visualisation of the oro-nasal fistula

the periosteal elevator may be carried around the cleft to allow the mucoperiosteum within the fistula to be rotated superiorly. This allows the full extent of the bony cleft to be visualized. Excess tissue within the nasal portion of the cleft can be trimmed, and then the nasal flaps are sutured to provide closure of the nasal floor. This helps in the closure of a persistent oro-nasal fistula (Figs. 74.6, 74.7, and 74.8). It is ideal to evert these flaps into the nose and to use inverted

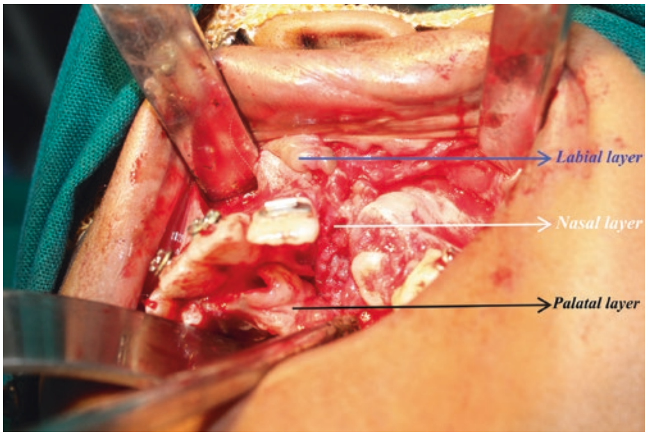

Fig. 74.8 Clinical picture demonstrating labial and palatal flap reflection and closure of nasal layer

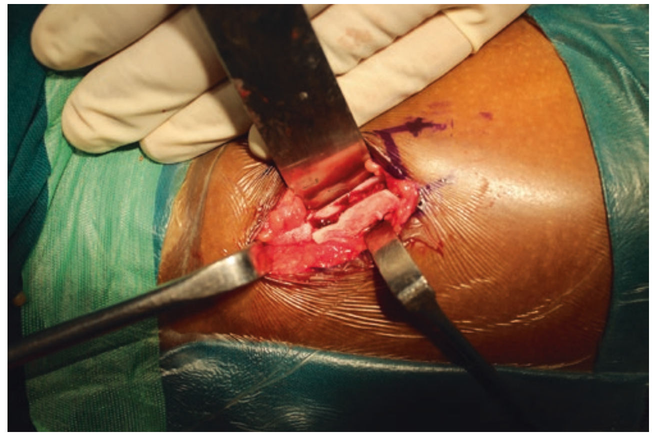

Fig. 74.11 Exposure of the iliac crest to harvest bone graft

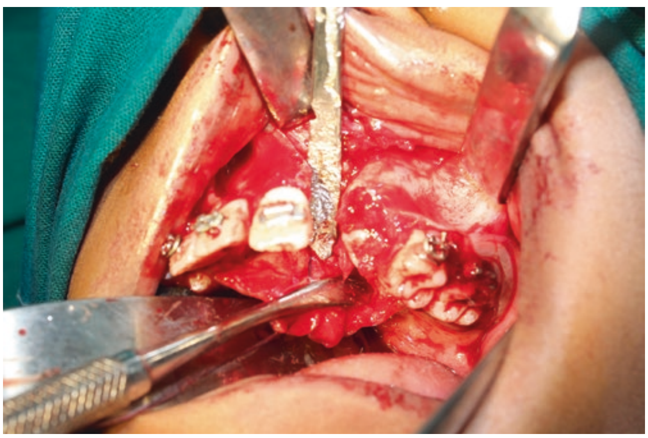

Fig. 74.9 Clinical step in which a periosteal elevator is used to define the alveolar cleft after closure of the nasal layer

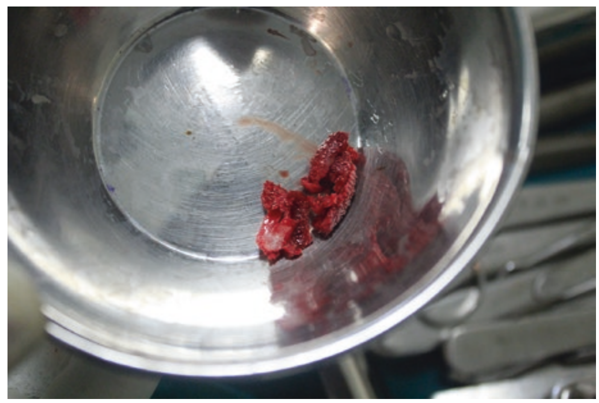

Fig. 74.12 Cancellous bone graft harvested from iliac crest

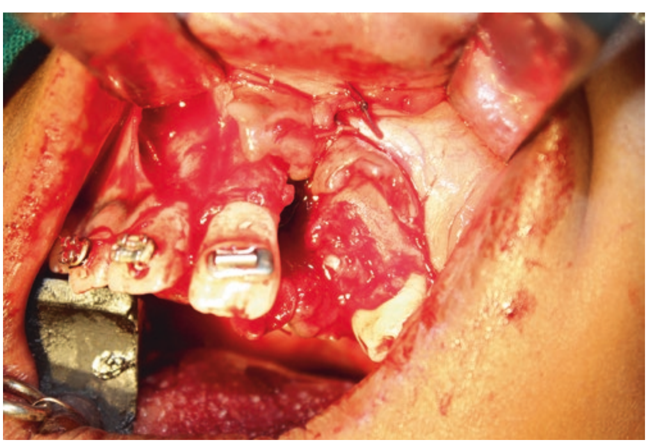

Fig. 74.10 Creation of a pouch with closure of the labial flaps in the alveolar cleft region to facilitate bone grafting

sutures so that the knots are on the nasal side. One should mobilize the palatal flaps toward the cleft (Fig. 74.8), utilizing releasing incisions if necessary. The palatal flaps may be sutured using interrupted sutures (Figs. 74.9 and 74.10).

The harvested bone is then (Figs. 74.11 and 74.12) condensed into a syringe prior to placement and packed tightly into the exposed bony cleft. While placing the bone graft, it is important to establish a normal contour to the pyriform aperture region. The labial flaps can be then advanced over the graft. This usually requires the utilization of the periosteal-releasing incisions made perpendicular to the direction of the advancement. A tension-free closure is mandatory for this technique (Fig. 74.13).

The two palatal and two labial flaps are then closed, utilizing a suture that simultaneously approximates all four corners. The final closure is completed with interrupted sutures closing the labial flaps and the interdental releases (Fig. 74.14). Closure is performed in a way that retains the attached gingiva overlying the reconstructed alveolus. Rarely, it may not be possible to obtain adequate advancement of flaps which necessitate the use of a cheek flap or a free gingival graft.

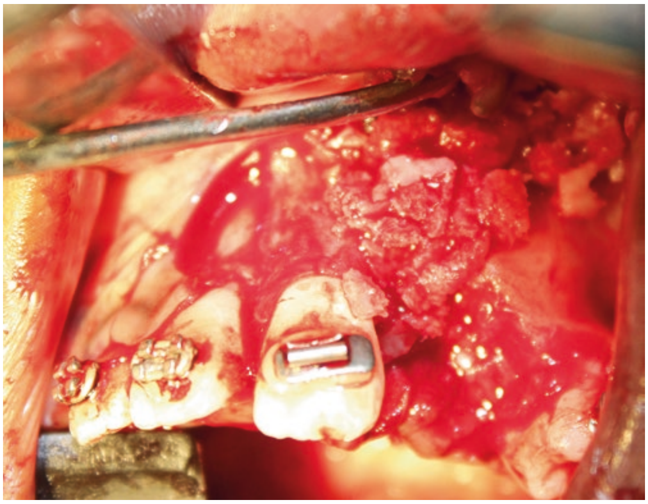

Fig. 74.13 Grafting of the alveolar cleft using harvested cancellous bone from the iliac crest

Fig. 74.14 Watertight closure of the alveolar cleft after grafting

74.5.5 Postoperative Assessment of Alveolar Bone Grafting

The success of alveolar bone grafting depends on certain outcomes, which include Box 74.5.

> **Box 74.5 Factors Determining Success of ABG**
> 1. Closure of the oronasal fistula.
> 2. Adequate bone support that allows eruption of the canine and support for adjacent teeth.
> 3. Architecture of the grafted bone.

Several scales are used to assess the success based on the above criteria. These scales use periapical, panoramic, or occlusal radiographs. A few of these scales are given below:

- *Bergland scale* [12] (Fig 74.15a–d).
  This scale is the gold standard of assessment, and success is judged based on the height of the post-graft interdental bone septum. It is assessed after the eruption of permanent canine. Four categories of success are defined, with

> Types I and II being satisfactory outcomes and Types III and IV being unsatisfactory:
> *Type I*: Interdental septum height is almost normal (<25% of bone resorption).
> *Type II*: Interdental septum height is equal to or greater than ¾ of the normal height (bone resorption 25%–50%).
> *Type III*: Interdental septum height is less than ¾ of the normal height (bone resorption 50%–75%).
> *Type IV*: Bone graft failure; no continuous bony bridge is visible across the cleft (bone resorption ≥75%) (Fig. 74.15).

- *Chelsea scale* [14] (Fig 74.16a–f).
  This scale evaluates the presence of bone in relation to the teeth adjacent to the cleft. Based on this, six categories have been identified. Only Types A and C represent satisfactory outcomes.

> *Type A*: Bone tissue is present at the cementoenamel junction of the teeth adjacent to the cleft. At least 75% of roots on either side are covered by bone.
> *Type B*: Bone tissue is present at the cementoenamel junction of the teeth adjacent to the cleft. At least 25% of roots on either side are covered by bone.
> *Type C*: Bone tissue is present and surrounds at least 75% of the roots on either side of the cleft, in an apical direction.
> *Type D*: Bone tissue surrounds at least 50% of roots on either side of the cleft, with an apical to coronal direction.
> *Type E*: Bone tissue bridge is present in the cleft, except in the apical and coronal directions.
> *Type F*: Less than 25% of bone tissue is present around both roots in the apical direction (Fig. 74.16).

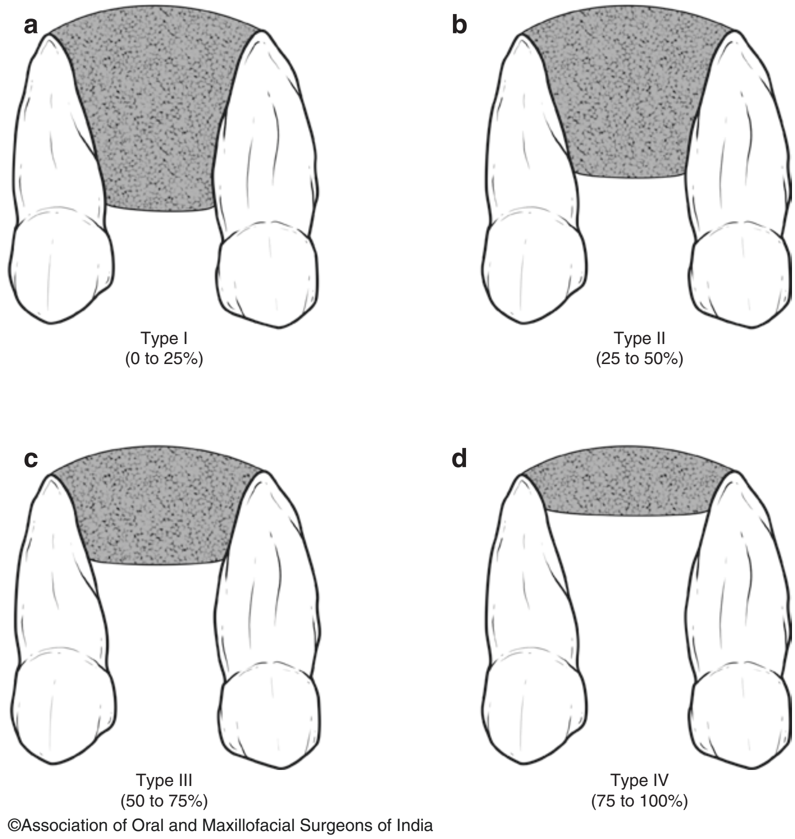

Fig. 74.15 (**a**–**d**) Bergland scale [13]

- *Trindade-Suedam scale* [15].
  These authors modified the Bergland scale described above and used alphabets to describe success or failure:

> *E* (*Excellent*): Interdental septum height is normal.
> *G* (*Good*): The bony septum is visible, with minimal disability.
> *R* (*Regular*): Bone graft is enough to allow for canine eruption. However, tooth movement is deficient, or a defect that is more than 25% of root length is seen.
> *B* (*Bad*): Deficient bone in the nasal region, which does not permit tooth movement.
> *F (Failure):* Bone graft is completely resorbed.

- *Kindelan scale* [16].
  This scale compares pre-operative and postoperative occlusal radiographs, to assess the percentage of bone fill. This also considers the eruption of the canine.

> Grade 1—Bone fill >75% (Fig. 74.17).
> Grade 2—Bone Fill 50–75%.
> Grade 3—Bone fill <50%.
> Grade 4—Complete absence of bone.

74.6 Complications of Alveolar Bone Grafting

The complications of alveolar bone grafting may be witnessed at the donor as well as the recipient site.

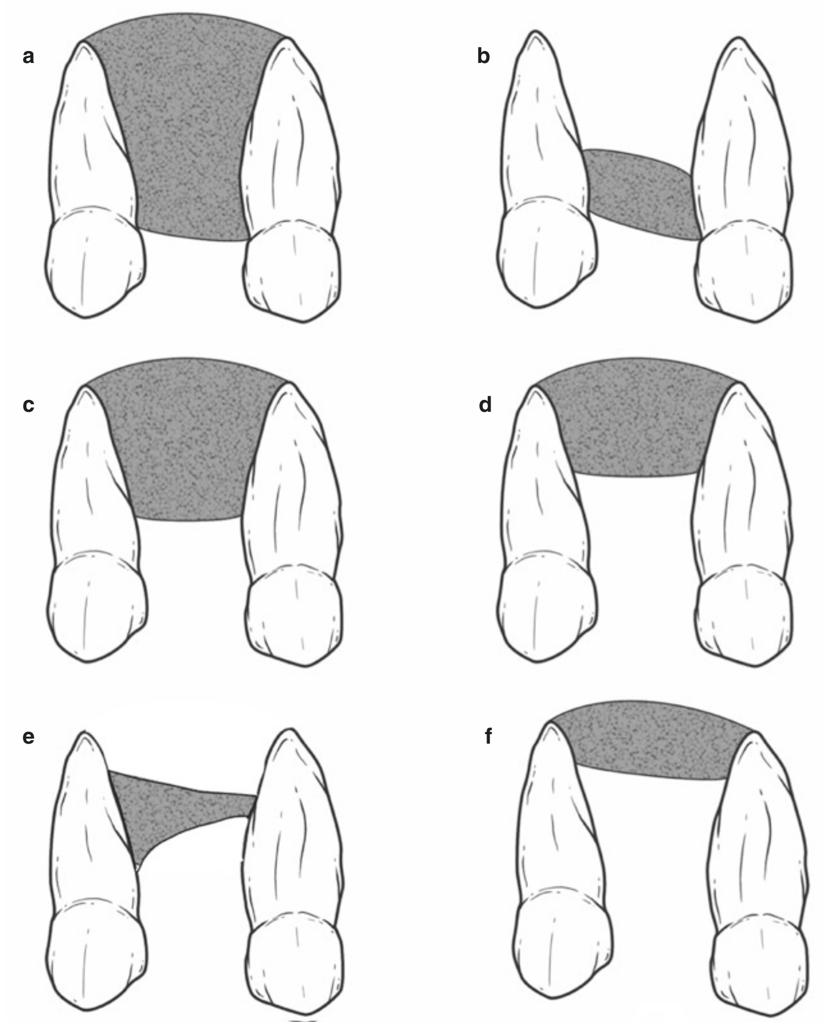

Fig. 74.16 (**a**–**f**) Chelsea scale [13]. (**a**) bone present at the Amelo-cemental Junction (ACJ) and covering 75% of both the roots, (**b**) bone present at the ACJ covering atleast 25% of both the roots, (**c**) bone covering atleast 75% of both the roots from the apical direction, (**d**) bone covering atleast 50% of the roots from the apical direction, (**e**) bony bridge present across cleft but no bone apically or coronally and (**f**) less than 25% bone cover from the apical direction

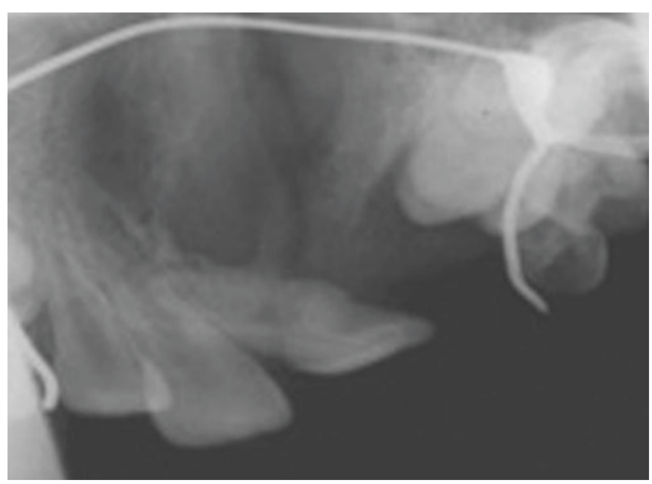

Fig. 74.17 Occlusal radiograph after bone graft with a Kindlean score of 1

74.6.1 Donor Site Complications

The site-specific donor site complications are highlighted in Box 74.6.

74.6.2 Recipient Site Complications

1. Damage to canine or central incisor roots.
2. Graft resorption: Graft resorption signifies complete failure of ABG, which can occur due to the following reasons:
   (a) Osteoresorptive cells and an environment suitable for bone resorption—this occurs with deciduous tooth extraction.
   (b) Excessive tension or trauma after surgery, resulting in exposure and loss of the graft.
   (c) Overpacking of the graft, causing alveolar notching and graft resorption. (d) Poor oral hygiene.

74.7 Conclusion

Alveolar bone grafting aims at restoring the functional integrity of the alveolar arch. In addition, they facilitate the eruption of teeth through the grafted bone into their respective positions. The timing of alveolar bone grafting is very crucial and can be effectively assessed by evaluating the thickness of bone covering the crown (of the lateral incisor or of the canine), rather than the degree of root formation of these teeth. The usage of autologous cancellous bone from the iliac crest is the most widely accepted graft in the mixed dentition period. In recent years, bone substitutes have also been used because of a tendency toward limited bone harvesting. These allograft or alloplastic sources of bone graft are especially useful in case of deficient donor autogenous bone material or to minimize donor site morbidity or in complicated cases. However, autologous bone is still the ideal choice for alveolar bone grafting, and none of the currently available methods can replace autologous bone completely. The future trend in alveolar bone grafting could be related to the usage of stem cells for bone regeneration; however many long-term clinical trials have to be conducted using stem cells to ensure its wide usage and cost-effectiveness.

Box 74.6 Donor Site Complications

(a) Iliac crest:
- Excessive blood loss.
- Hematoma.
- Delayed wound healing.
- Long and adherent and scars under belts or clothing which may be painful.
- Hypoesthesia or anesthesia over the lateral femoral cutaneous nerve and in its distribution areas.

(b) Cranium:
- Risk of inner table penetration.

(c) Rib grafts:
- Postoperative chest infection.
- Pneumothorax.

(d) Mandible grafts:
- Injury to mental nerve.

Disclosure Authors have no financial conflicts to disclose.

74.8 Case Scenarios

Case 1 (Fig. 74.18a–f)

An 11-year-old female patient who was treated for unilateral cleft lip and palate on the left side presented with the complaint of leakage of fluid from the nose and escape of air from the oral cavity. She had undergone primary unilateral lip repair when she was 6 months old, and a palatal repair was done when she was 2 years old.

Procedures, which were performed at this stage—fistula closure and alveolar bone grafting.

A sulcular incision along with incision around the fistula was performed both on the labial and palatal side so to enable direct access to the fistula and bony defect. Oral and nasal layers were separated. The nasal layer was initially closed in a watertight manner. Cancellous bone graft was obtained from the iliac crest, and the bone graft was placed into the defect, and watertight closure was obtained.

Future treatment required—pre-surgical orthodontics, orthognathic surgery, post-surgical orthodontics, and rhinoplasty (if required).

Case 2 (Fig. 74.19a–j)

Case Presentation

A 10-year-old female patient who was diagnosed with unilateral cleft lip and alveolus on the left side (Fig. 74.19a, b) reported to us with a chief complaint of leakage of fluid from the nose. She had previously undergone primary lip repair at 8 months of age. An OPG and IOPA revealed the extent of alveolar cleft (Fig. 74.19c, d). Pre-surgical orthodontic treatment was started to align the teeth and facilitate the eruption of 23 (Fig. 74.19e).

Procedures, which were performed at this stage—fistula closure and alveolar bone grafting.

A sulcular incision was placed around the involved teeth both on labial and palatal sides which exposed the fistula and the alveolar defect. A careful dissection was performed so as to separate the nasal layer and oral layer. The nasal layer was initially closed in a watertight manner. An adequate quantity of cancellous bone graft was harvested from the iliac crest. Thus obtained bone graft was placed into the alveolar defect, and a watertight closure was performed (Fig. 74.19f). The alveolar bone graft was assessed 6 months post-surgery using IOPA (Fig. 74.19g). The orthodontic treatment was completed after facilitating the eruption of canine and achieving leveling and alignment of teeth (Fig. 74.19h, i, j).

Future treatment required—Patient has to be assessed after growth completion, and if required the following treatment will have to be carried out:

- Pre-surgical orthodontics.
- Orthognathic surgery.
- Post-surgical orthodontics.
- Rhinoplasty.

Fig. 74.18 (**a**–**f**) (**a**) Extraoral frontal picture at rest. (**b**) Extraoral frontal picture at smile. (**c**) Intraoral picture demonstrating fistula. (**d**) Palate post-repair. (**e**) Creation of a pouch in the alveolar cleft region to facilitate bone grafting. (**f**) Grafting of the alveolar cleft using harvested cancellous bone from the iliac crest. (Fig. 74.14 shows Watertight closure of the alveolar cleft case shown in Fig. 74.18, after grafting)

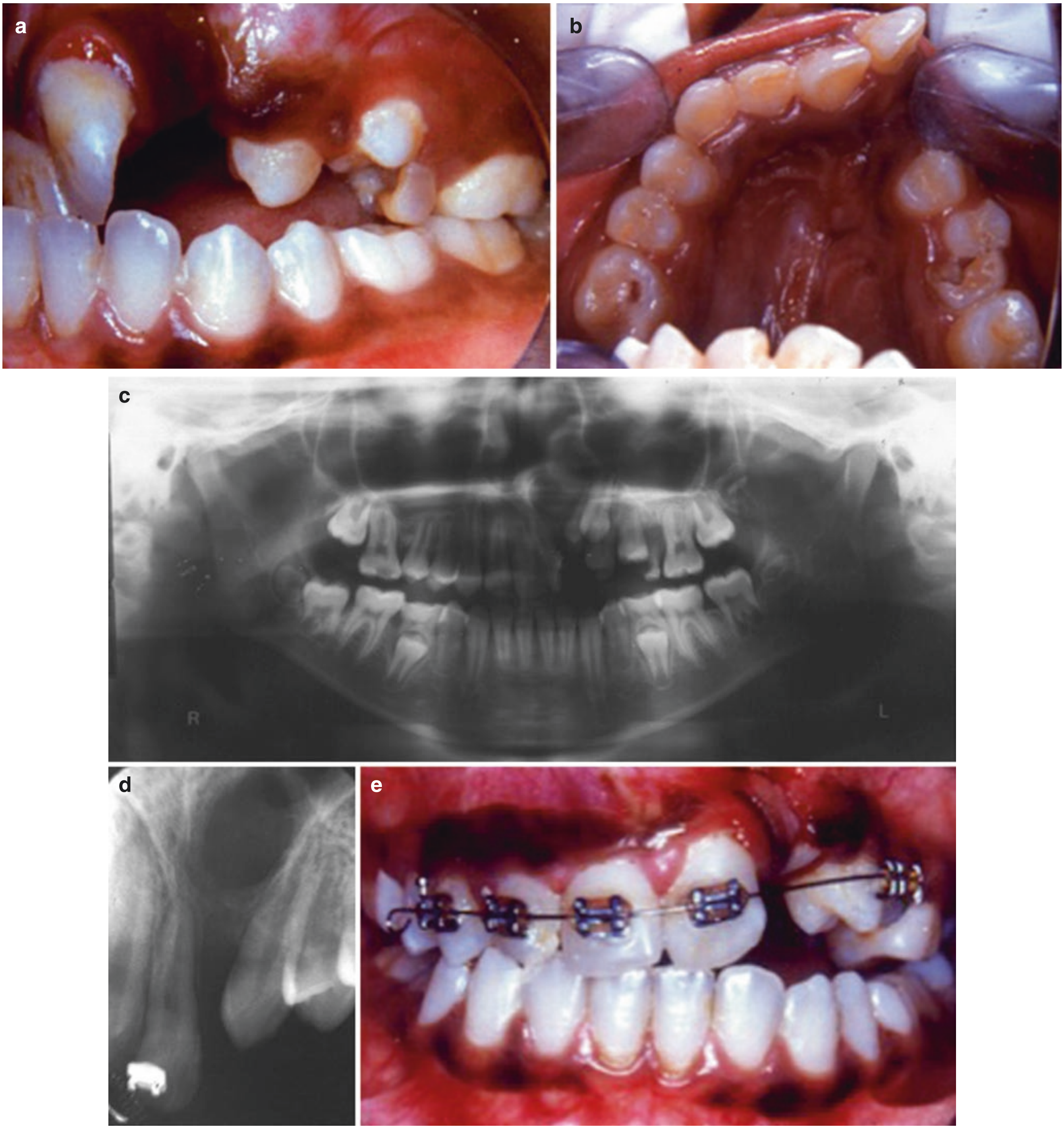

Fig. 74.19 (**a–j**) (**a**) Intraoral frontal picture demonstrating alveolar cleft on the left side of maxilla and associated fistula. (**b**) Intraoral maxillary occlusal picture demonstrating alveolar cleft and fistula. (**c**) OPG demonstrating the alveolar cleft on the left side and the eruptive status of the upper left permanent canine. (**d**) IOPA demonstrating the presence of alveolar cleft between upper left central incisor and upper left canine. (**e**) Intraoral frontal picture. Orthodontic treatment to facilitate tooth alignment and eruption of permanent upper left canine. (**f**) Intraoral picture demonstrating the completion of alveolar bone grafting. (**g**) IOPA demonstrating the uptake of alveolar bone graft in the region of alveolar cleft between upper left central incisor and upper left canine. (**h**) Intraoral frontal picture demonstrating orthodontic treatment. The permanent canine on the left side has been clinically moved to the occlusal plane. (**i**) Intraoral maxillary occlusal photograph post-orthodontic treatment demonstrating the eruption and alignment of upper left canine in the alveolar arch. (**j**) Intraoral photograph post-orthodontic treatment demonstrating the eruption and alignment of upper left canine in the alveolar arch

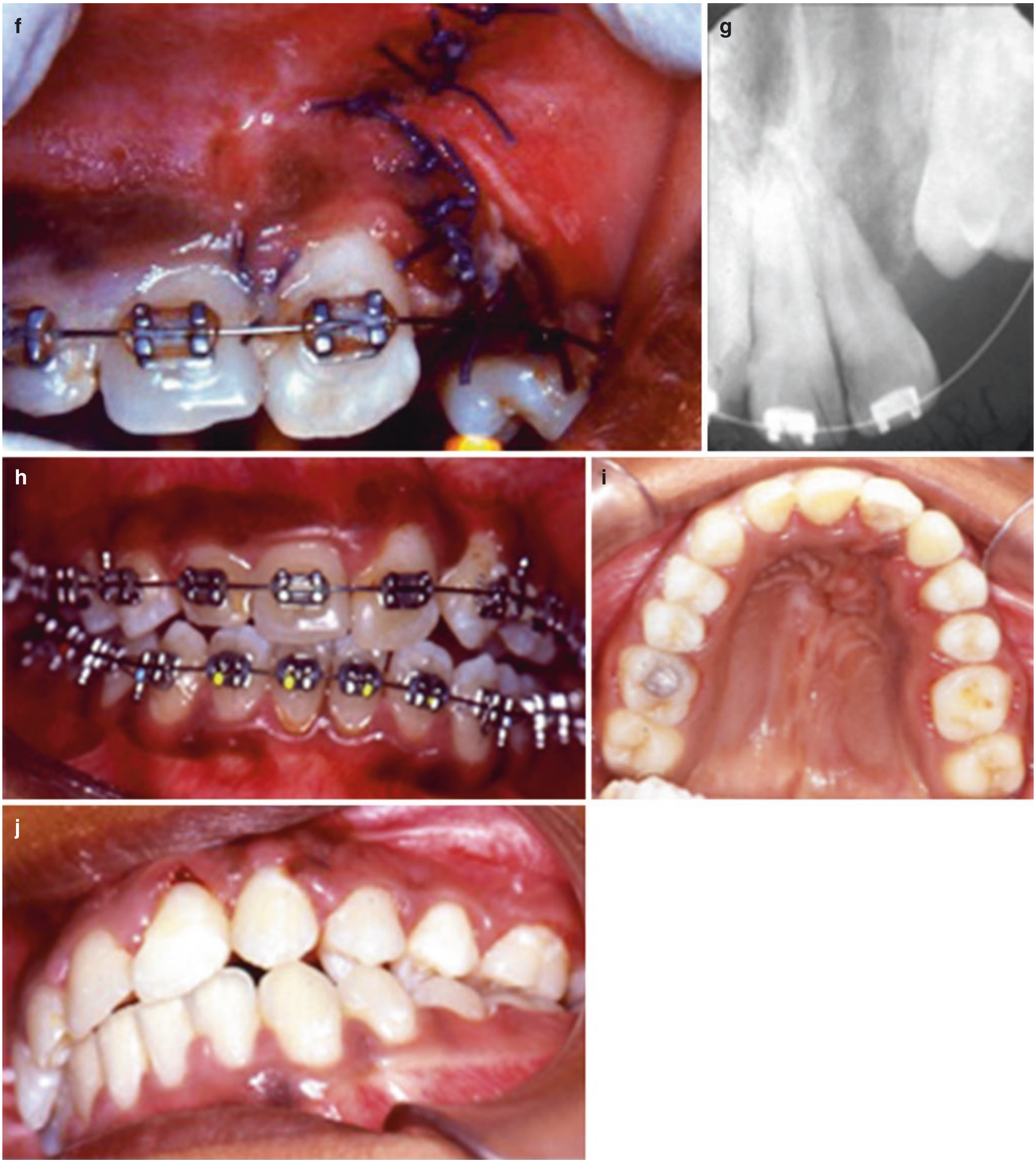

Fig. 74.19 (continued)

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