Bone Graft in Alveolar Cleft Lip and Palate

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16.1 Introduction

In the beginning of the twentieth century descriptions about alveolar bone graft were reported but only in the middle of this century it became to be more studied (Daw and Patel 2004). Just after basic principles for bone graft integration were very well established bone graft for alveolar cleft became to be used by surgeon worldwide. Alveolar bone grafting in secondary dentition is considered nowadays the golden standard for cleft patient rehabilitation.

There are two very important aspects for cleft patient rehabilitation. Maxillary arch stabilization and tooth preservation are key points that must be emphasized (Daw and Patel 2004).

In 1972, Boyne and Sands found that marrow cancellous cells could survive in fresh autograft when used in alveolar area if they were well covered by local flaps. They proposed the technique that is still used today for most of the cleft team (Boyne and Sands 1972; Boyne 1974). Abyholm subsequently demonstrated that secondary alveolar bone grafting and orthodontic treatment resulted in space closure in 90% of cleft patients and had no impairment to the facial growth.

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They concluded that the optimum age for grafting would be between 9 and 11 years, when the facial sutures involved in the surgical procedure could not be disturbed (Abyholm et al. 1981).

The orthodontic treatment and facial growth analysis have shown the importance of the alveolar bone grafting in the mixed dentition before the canine eruption**.** Today, it is widely considered an essential step in the treatment process of patients with facial clefts (Eppley and Sadove 2000).

The goals and well-established benefits of alveolar bone grafting for the repair of maxillary defects include the stabilization of the maxillary arch (Skoog 1965; Epstein et al. 1970), the elimination of the oronasal fistula (Jolleys and Robertson 1972), the creation of bone support for permanent tooth eruption, and the reconstruction of the pyriform aperture. As these changes lead to better support for the soft tissues of the nasal base, any patient with a facial cleft is a candidate for alveolar bone grafting (Waite DEK 1980).

There are many possible variations in the extent of the alveolar defect, ranging from only one notch on the incisal side of the alveolar process to large defects with widely separated alveolar segments.

In unilateral clefts, the cleft side is usually named as a minor segment of the maxilla. Due to the lack of continuity and stability, cross-sectional collapse of the jaw is quite common. These patients have crossbite due to the collapsed arch, which is particularly noticeable in the projection of the canine and first premolar on the cleft side. Pre-maxilla position is also variable, with either normal or rotated alignment. The central incisor adjacent to the cleft is usually rotated and set at an angle. The lateral incisor may be absent (between 10 and 30% absent (da Silva Filho et al. 2013)), but it is often hypoplastic, malformed, or substituted by a supernumerary tooth. Sometimes, the tooth may erupt in the alveolar cleft region, or it may be present in the nasal cavity or palate.

Bilateral clefts also have variable presentations. These clefts may be of different lengths and widths, and are not necessarily symmetrical. The pre-maxilla is usually rotated in relation to the lateral segments due to excessive and uncontrolled growth of the vomer-pre-maxillary suture. The pre-maxilla may also be placed inferiorly (overbite) or aberrantly rotated in the coronal and sagittal planes.

The embryological development of facial processes and primary dental germ occurs simultaneously. Thus, it is not uncommon to have tooth malformation or absence adjacent to the cleft. These teeth can be malformed, misplaced, or missing, as in the agenesis of the lateral incisor, with or without the presence of supernumerary teeth. Moreover, the patient's pattern of deciduous dentition will predict the permanent dentition, although the permanent dentition is more significantly altered.

The objectives of alveolar bone grafting include both functional and aesthetic aspects (Wood et al. 1997). Functional objectives include:

1. Allowing the eruption of permanent tooth (canine) in the grafted area
2. Providing bone support to the teeth adjacent to the cleft
3. Creating a continuous and stable maxillary arch, allowing security in orthodontic mobilization
4. Closing the oronasal fistula
5. Facilitating oral hygiene

The maintenance of the oronasal fistula and chronic nasal regurgitation of fluids usually leads to chronic inflammation of the nasal mucosa with continuous secretions. This can cause significant psychosocial issues.

The aesthetic goals include filling the nostril, restructuring the nasal base, and creating a maxillary arch, all of which contribute to a more satisfactory aesthetic appearance and a more beautiful smile.

Some authors prefer conducting gingivoperiosteoplasty only at the time of primary lip treatment. This creates a cavity that can then be filled with bone created due to the effects of local growth factors (Wood et al. 1997; Cohen et al. 1989). Many studies showed no neo-bone formation or even some studies presented important disturbance in facial growth (Friede and Johanson 1974). Preoperative orthopedic alignment of the teeth is necessary to allow for better visualization of the size of the gap in the maxilla and then provide good reestablishment of the alveolar ridge (Cohen et al. 1993).

Alveolar bone grafting can be performed at different times during facial and dental development. This procedure is called *primary bone grafting* when it is performed on children under 2 years old, and *secondary bone grafting* after this age. Secondary bone grafting can be subdivided into three phases: *early secondary*, when the patient still has its deciduous teeth (between 2 and 5 years old); *transitional secondary*, before the eruption of the definitive canines (between 6 and 12 years); and *late secondary or tertiary*, after the eruption of the canines (after age 12) (Eppley and Sadove 2000; Rosenstein et al. 1991).

The ideal age for alveolar bone grafting still remains in discussion, but most of the cleft centers used the age between 8 and 12 years before the canine eruption as the landmark. The few groups that use primary grafting argue that it both reduces the need for orthognathic surgery and leads to lower rates of cross-jaw collapse, thereby decreasing the time needed for orthodontic upper arch correction (Eppley and Sadove 2000; Rosenstein et al. 1991). Those teams in favor of secondary grafting believe that gingivoperiosteoplasty and primary bone grafting lead to a higher incidence of occlusal changes and maxillary growth deficiencies (Jolleys and Robertson 1972; Friede and Johanson 1974). In addition, they believe that the quality of bone formed or grafted from primary grafting is not suitable for orthodontic restoration.

Most treatment centers believe that the best time for grafting should be based on a combination of factors: tooth development, orthodontic state, no disturbance for facial growth, and good surgical conditions. Of these, tooth development, more than chronological age, should be the main factor when determining the appropriate time for bone grafting. It is widely accepted that bone grafting should be conducted during the initial phase of mixed dentition—after the eruption of the permanent medial incisor but before the final canine eruption. This helps to preserve the largest possible number of adult teeth. At this time—usually around age 9—the sagittal and transverse maxillary growth is complete, and the vertical growth remaining requires the eruption of permanent teeth to occur (Bjork and Skieller 1974). In patients with tooth bud of lateral incisor, bone grafting may be performed earlier, between 7 and 8 years of age, to preserve this tooth.

16.2 Orthodontic Management

The orthopedic approach for maxilla is generally started around 5 years of age. The principle is to allow for better alignment of the upper dental arch and to minimize maxillary collapse.

Prior to bone grafting, the alveolar arches should be aligned. In this sense, it is advisable to place a palatal device to increase the transverse diameter of the maxilla, adjusting it to the lower dental arch. This will facilitate the surgical procedure. However, maxillary expansion can be performed after the alveolar grafting, but with more difficulty, since alveolar continuity was created. It is clear that alveolar grafting without prior orthopedic treatment leads to poor results, with bad bone alignment maintenance, maxillary collapse, and posterior crossbite (Vlachos 1996) (Fig. 16.1).

Bone grafting surgery is only postponed in the case of bad dental conditions such as cavities and gingivitis. These must be treated before surgery to minimize the risk

Fig. 16.1 Preorthodontic treatment before and after ABG. (**a**) Unilateral left cleft, (**b**) maxilla expansion, (**c**) intraoral view of the device, (**d**) after expansion with ABG, (**e**) contention after ABG and maxillar expansion

of postoperative infections and subsequent bone grafting failure. If dental extraction is required, it should be done 8 weeks prior to grafting to provide adequate time for the manipulated alveolar region to heal.

The orthodontist has a fundamental role in the treatment of these patients, with different techniques necessary during different stages of facial growth. In childhood, maxillary orthopedics may be necessary to improve arch alignment by shaping the maxillary arch. After alveolar grafting, the orthodontist continues treatment by correcting the remaining crossbites, aligning or rotating the incisors, and improving function and dental aesthetics.

16.3 Selection of Bone Donor Site

Initially, surgeons utilized cortical bone blocks from the iliac and ribs, with the main goal of horizontal stabilization of the jaw to prevent jaw collapse and crossbite. Subsequently, however, it was noticed that using cancellous bone would lead to better results because it would be more readily incorporated into adjacent bone (Boyne and Sands 1972; Boyne 1974). Cancellous bone provides more uniform grafting integration and allows more effective tooth eruption. The most commonly used local donor sites are now the iliac crest (Abyholm et al. 1981) and the cranium (Abyholm et al. 1981; Kalaaji et al. 1994). The iliac crest contains a large amount of bone marrow and can be collected simultaneously with the grafting procedure. Using the cranium enables retrieval of a large amount of bone from the same embryological lineage as the transplant site (membranous bone), and it is virtually painless; however, this bone needs to be crushed. There are also centers using tibial grafts, rib, and chin (Sindet-Pedersen and Enemark 1990; Witsenburg et al. 1990).

The current gold standard for cellular grafting is the bone marrow collected from the iliac crest. This is because the iliac crest provides the greatest amount of bone marrow out of all possible donor sites and has a success rate greater than 80% (Forte et al. 2012). The biggest criticism of the use of the crest is out of concern for morbidity of the donor site, which can be minimized by limiting the detachment of muscle and periosteum adjacent to the bone marrow collection site (Rudman 1997) (Fig. 16.2).

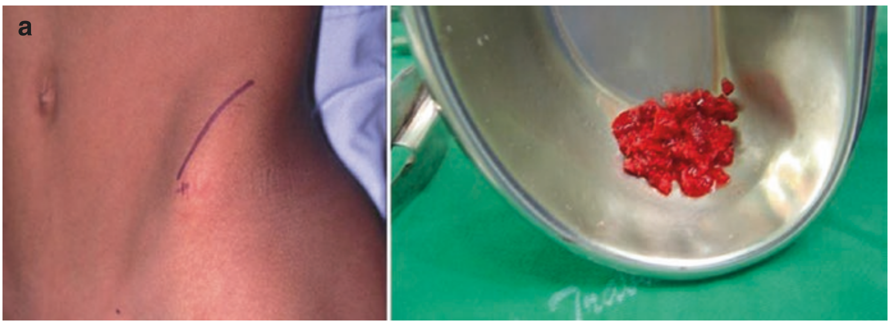

Fig. 16.2 Bone donor-site iliac crest. (**a**) Position of the incision. (**b**) Internal cortical of ilium bone. (**c**) General view of donor site

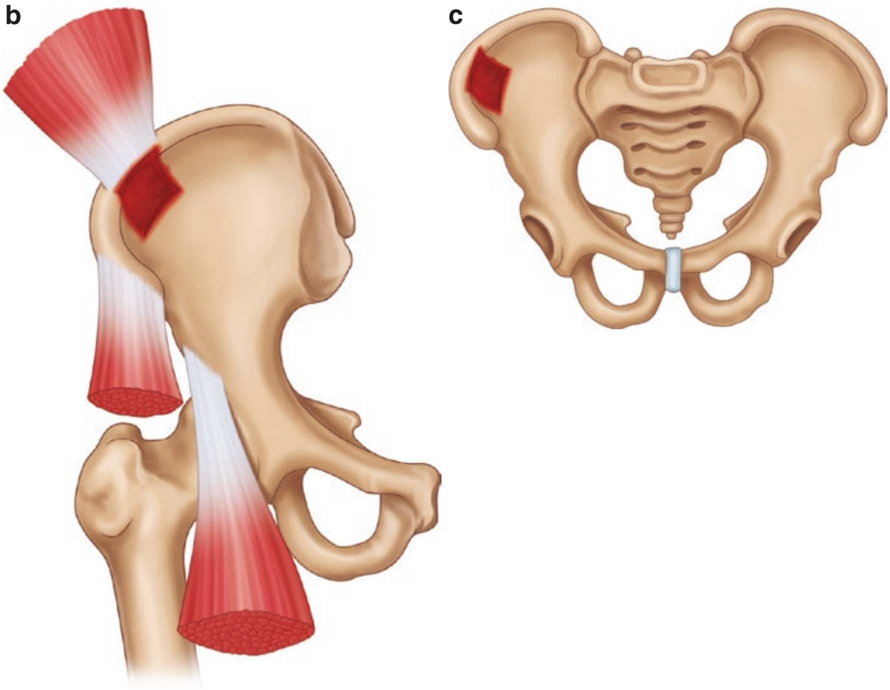

Fig. 16.2 (continued)

Some bone substitutes such as bone morphogenetic protein (BMP) are also in use today. BMP is a member of the transforming growth factor (TGF) group, which stimulates cells—osteocytes—to multiply and produce bone. These bone substitutes are placed in the cleft area, which is then closed through periosteoplasty (Alonso et al. 2010). Although bone substitutes have led to excellent results, their high cost still restricts use.

16.4 Surgical Technique

Patients undergo general anesthesia with local anesthetic using a solution of saline, bupivacaine, and epinephrine in a dilution of 1:120,000 U.

The surgical procedure is conducted using the technique described by Boyne and Sands (1972). The general principle is to manufacture a tissue layer that can fully cover the graft, therefore avoiding its exposure to the oral cavity (Fig. 16.3).

After the incision on the margins of the alveolar cleft, the mucoperiosteous flaps are elevated to the anterior alveolar surface, on the vestibular side of the gingivolabial mucosa. The lateral incision extends into the vestibule on the upper projection of the permanent molars, making that the flap's point of rotation, with an incision parallel to the teeth roots. The next step is to proceed to broad detachment and

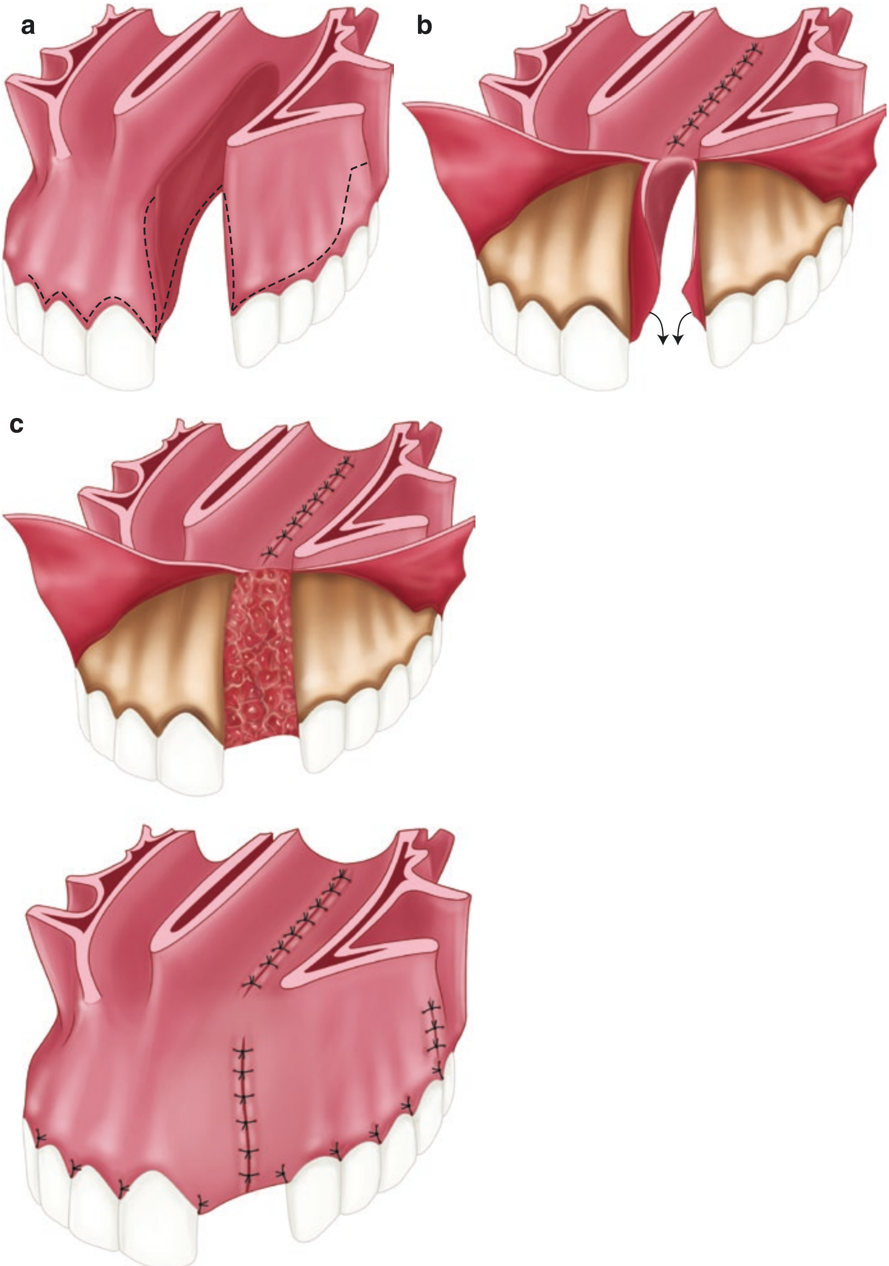

Fig. 16.3 Alveolar bone grafting technique. (**a**) Demarcation of the incision oral and nasal site. (**b**) Three flaps raised. (**c**) Closure of the flap with bone graft chips

maxilla exposure in the anterior region with the nostril opening. The cleft edges are elevated, separating the alveolar flaps laterally and the septum medially.

These flaps should be divided on each side near the hard palate to create two flaps to close the nasal floor superiorly, and two flaps to close the palatal mucosa inferiorly. This creates a space surrounded by alveolar bone on each side, above and below, with flaps separating the nasal and oral cavities. The iliac crest bone graft is then placed through the anterior opening.

The suture of gingival periosteal flap should be performed without tension through periosteal incision inside the flap side, allowing its medial rotation and advancement.

With the patient positioned supine with a pad in the gluteal region to raise the iliac spine and anterior superior iliac crest, a 4-cm incision is made in a lateral line parallel to iliac crest. It is important to avoid the area just below the anterior superior iliac spine, through which the lateral femoral cutaneous nerve traverses. With an electric cautery, dissect the subcutaneous plane, fascia, muscle, and periosteum overlying the iliac crest. Care must be taken in children, in whom there is cartilage in the upper portion of the iliac crest. In these cases, the osteotomy is performed more internally, below the growth plate. Detachment of periosteum on the internal side of the crest is performed to allow access to the cortical surface. An osteotome is used to make a window into the cortical bone, exposing the bone marrow that can then be collected with curettes and stored in a sterile tank with saline.

After removing a sufficient amount of bone graft, hemostasis should be achieved using bone wax and reposition the cortical bone. The fascial planes are closed with continuous suture with 3.0 polygalactin stitches and the subcutaneous and deep dermis with interrupted sutures. The superficial skin is closed with intradermal continuous suture of 4.0 polygalactin.

Little importance was initially given to planning the mucoperiosteal flap that would be used to cover the grafted bone but this is crucial for the final functional result (Backdahl 1961). Histologically, the masticatory mucosa is composed of a keratinized squamous epithelium layer and a dense, firm lamina propria layer with static ligaments towards the alveolar bone and tooth roots. This structure provides support and protects the masticatory apparatus from minor damage and bacterial contamination (Friede and Johanson 1974).

The mucoperiosteal flaps are the best option for covering bone grafts. These flaps allow cleft reconstruction using tissue that is similar to the adjacent structures in terms of color, texture, and strength. Moreover, the tooth can then erupt through keratinized tissue, which does not occur if the tissue is only composed of mucosa (Cohen et al. 1989).

In the first week after surgery, patients are placed on a cold liquefied diet and receive analgesics and symptomatic medication. After 2 weeks, patients can be advanced to a soft diet for 4 weeks. They are advised to avoid biting with their incisors for 4 weeks. Oral hygiene is encouraged after each meal by rinsing their mouths with 0.12% chlorohexidine gluconate solution. Due to the graft withdrawal from the iliac crest, patients are suspended from physical activities for 2 months. Stitches on the donor area are removed about 7 days after surgery (Fig. 16.4).

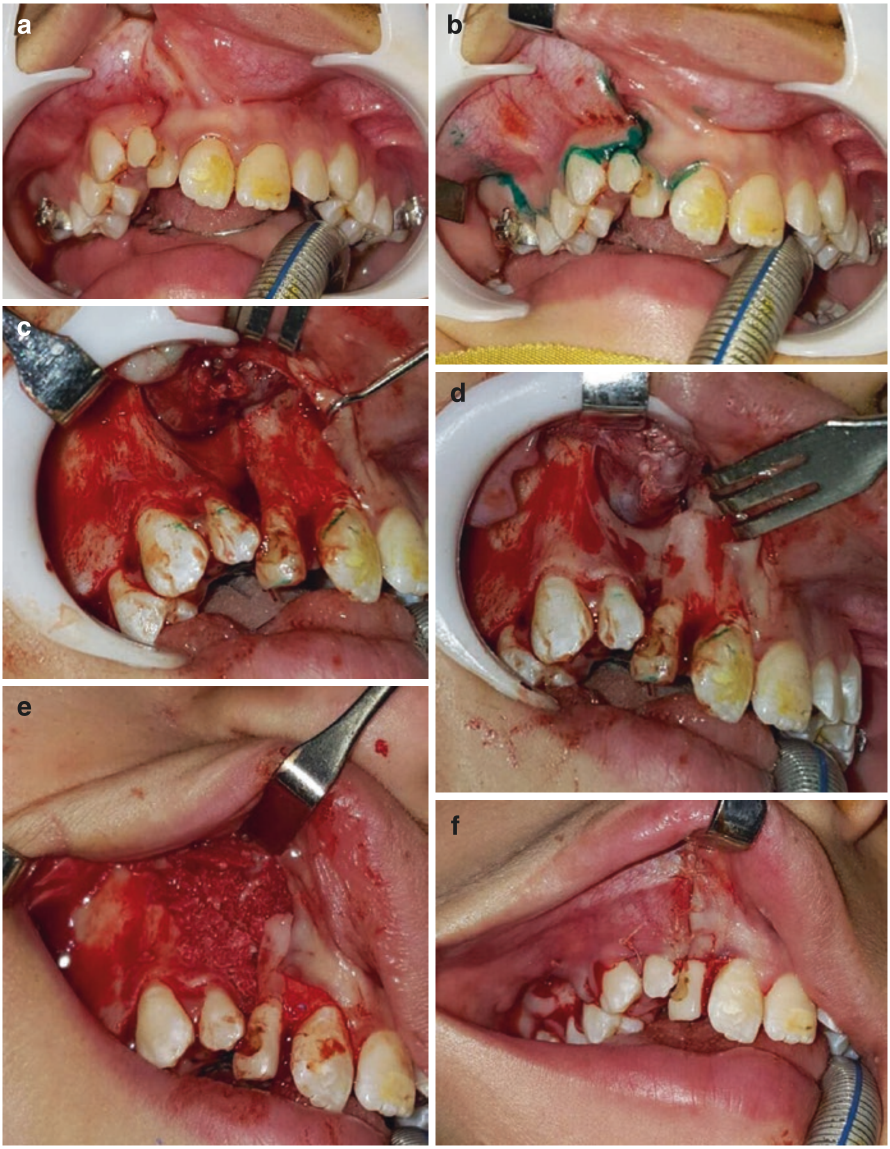

Fig. 16.4 Intraoperative steps of ABG surgery. (**a**) Right alveolar cleft, (**b**) demarcation of gingival flap, (**c**) bone cleft exposed, (**d**) closure of nasal lining, (**e**) medullary bone chips in the defect, (**f**) final aspects of the flap rotation

Outpatient follow-up consists of weekly revaluations in the first month. In each visit, patients are assessed for pain, signs of fever, edema, and erythema beyond the mucosa, and potential graft exposure due to evolution of the scar.

After the first month, reassessments should be made in 3 months to monitor mucogingival healing and tooth eruption. After 3 months, patients can resume periodic evaluations with the orthodontic team (Fig. 16.5).

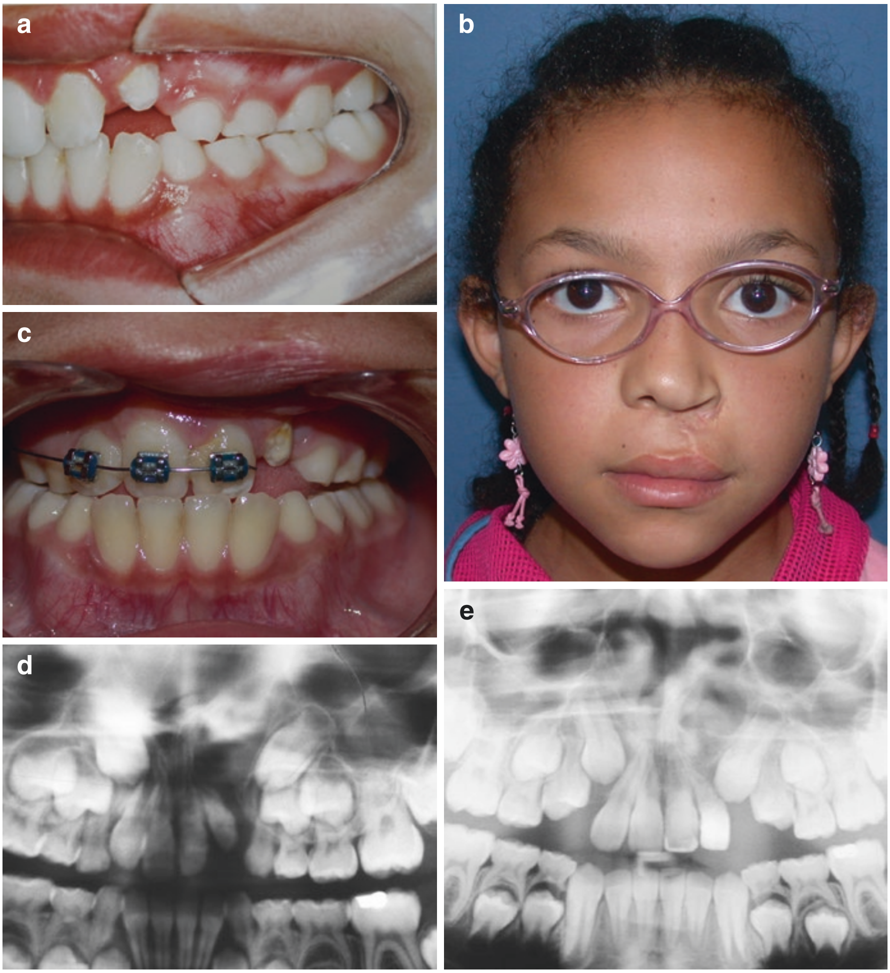

Fig. 16.5 Long-term outcomes of ABG with images. (**a**) Left alveolar cleft at mixed dentition, (**b**) cleft patient, (**c**) orthodontic preparation for ABG, (**d**) panorex at 7 years old, (**e**) panorex after ABG, (**f**) panorex after ABG with canine in position, (**g**) panorex 8 years late, (**h**) final occlusion at 16 years old, (**i**) CT scan at 17 years old, (**j**) final facial appearance

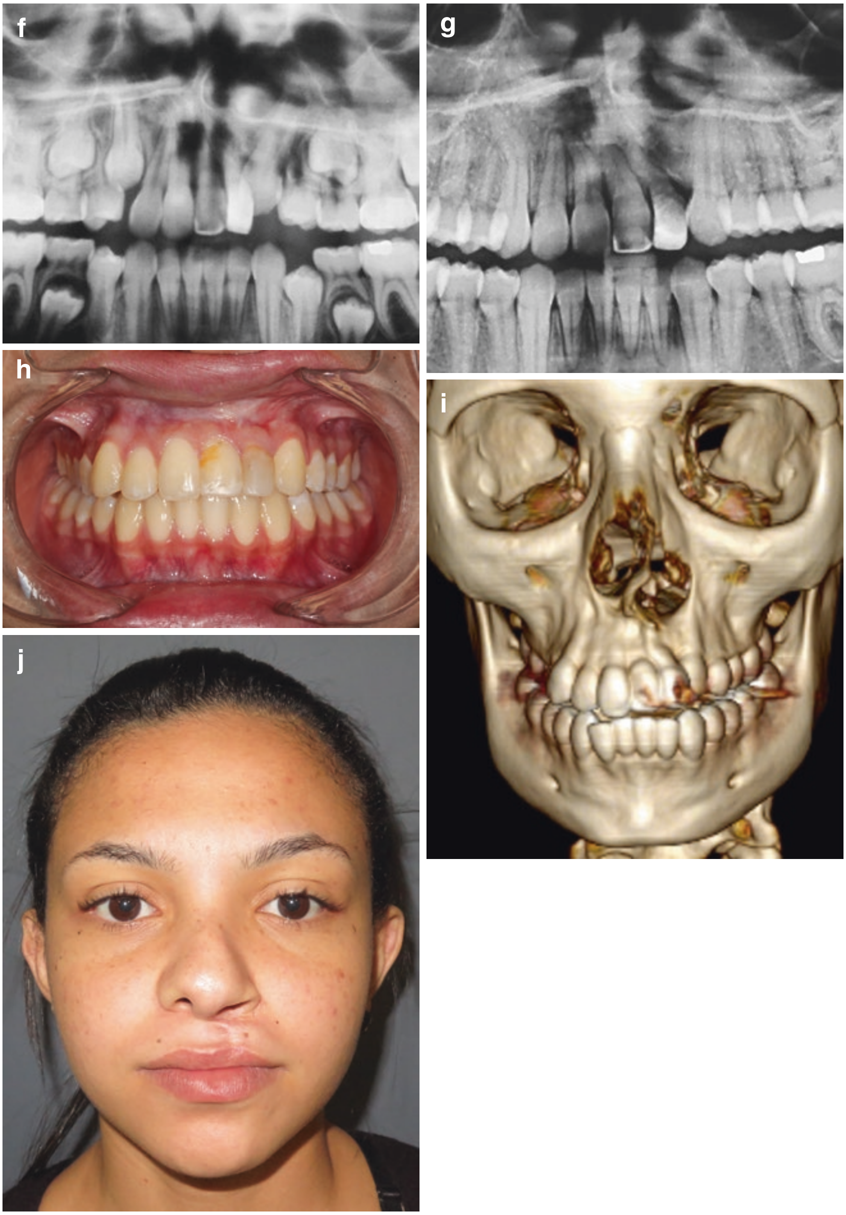

Fig. 16.5 (continued)

However, some authors preferred to use minimally invasive techniques for iliac bone graft harvesting. Consistently lower morbidity (e.g., donor-site pain and gait disorders) in patients who underwent closed techniques has been shown by our group (SOBRAPAR) and others (Sharma et al. 2011; McCanny and Roberts-Harry 1998; Raposo-Amaral et al. 2015).

Surgery using minimally invasive techniques has been performed with patients in the supine position under general anesthesia. Two techniques have been used to harvest medullar bone for alveolar grafting. The techniques varied by the extent of periosteal elevation and diameter of the extractor devices. Incision of 1.5 to 2 cm and subcutaneous undermining allowed the inclusion of bone extractor on the surface of the iliac crest with minimal periosteal flap elevation. Following, a periosteal flap elevation (or not) was preceded until at least 4 cm deep from the most superficial point of the anterior-superior iliac crest where the presence of bone could be detected by subtle pressure of the instrument against the bone structure. Rotational movements of the extractor were performed until the absence of resistance and then a block of cancellous bone was obtained to be used in the alveolar region (Raposo-Amaral et al. 2015) (Fig. 16.6).

Fig. 16.6 Minimal invasive bone grafting harvesting. (**a**) Cylinder bone extractor devices. (**a**) Both devices present a metallic cylindrical rod with a cutting edge and the other edge with "T" or "circle" cable that allows firm grip during iliac crest bone graft harvesting. (**b**) Note the differences in diameter (5 mm [*left*] and 8 mm [*right*]). (**b**) Minimal incision marked at iliac crest and rotational movements of the extractor were performed until the absence of resistance and then a block of cancellous bone was obtained. (**c**) The harvested bone inside the metallic cylindrical rod. Note that 3–5 blocks of bone can be easily removed

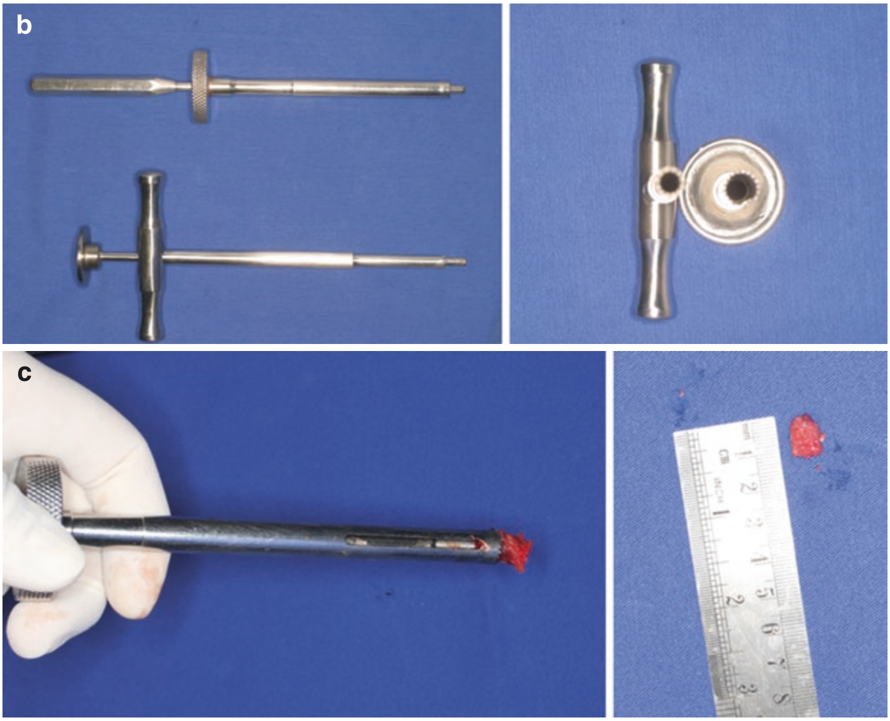

Fig. 16.6 (continued)

In Brazil, as spending of specialized centers in the multidisciplinary management of craniofacial deformities has been financed only partially (50–60% of overall costs) by the Unified Health System (SUS; Ministry of Health, Brazil), any factors that may impact the overall costs of treatment of cleft patients should be considered when choosing between different surgical devices. Thus, we have adopted both surgical devices due to low financial cost to obtain and maintain the materials, if compared, for example, to the industrial electrical devices that have greater financial cost (Raposo-Amaral and Raposo-Amaral 2012).

16.5 Future Perspectives

Tissue engineering has had significant advancements in protein factors with the potential to induce osteogenesis and inhibition in order to maximize the action of BMPs. Studies on stem cells with osteogenic potential from bone marrow or pluripotent cells harvested by liposuction and other sources as muscle of the elevator *palatine* are also promising in the future acquisition of techniques for bone reconstruction in patients with craniofacial deformities (Raposo-Amaral et al. 2014; Freihofer et al. 1993) (Fig. 16.7).

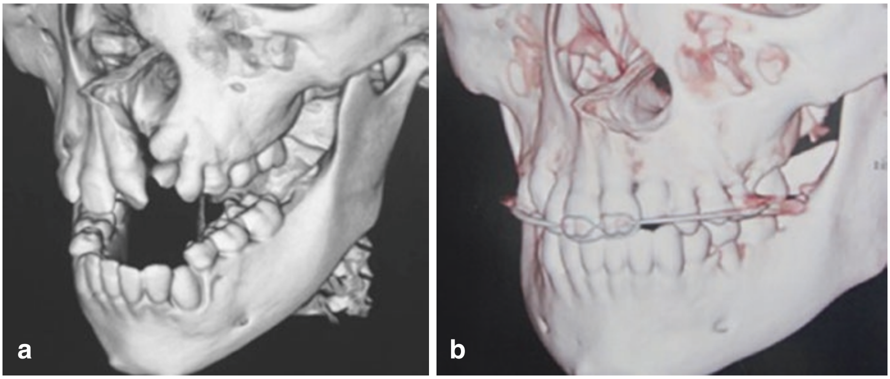

Fig. 16.7 Future bone substitutes. (**a**) Preoperative computerized tomography imaging of the craniofacial skeleton of a patient with complete unilateral cleft lip and palate. (**b**) Postoperative computerized tomography imaging of the craniofacial skeleton after alveolar reconstruction utilizing BMP

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