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Evaluation of bone volume following bone grafting in patients with unilateral clefts of lip, alveolus and palate using a CT-guided three-dimensional navigation system

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SUMMARY. Purpose: **In cleft patients the eruption of the permanent canine depends very much on the amount of bone available following bone grafting. The purpose of this study was to evaluate the initial defect in alveolar clefts and the volume of bone bridging found in unilateral clefts which had undergone bone grafting.** Patients and Methods: **To determine the fate of the bone graft in cleft palate patients a three-dimensional CT-based Navigation System (Zeiss, Aalen, Germany) was used. CT scans of 16 patients with unilateral clefts were taken immediately preoperatively and 1 year postoperatively. The patients underwent surgery between the age of 9 and 14 years using iliac crest bone grafts. The data was transferred to the work station of the navigation system. Using the STN software, the defect at the alveolar clefts and volume of the bone grafts were determined in each case. Three-dimensional models were created showing the amount of bone immediately preoperatively and 1 year postoperatively.** Results: **The size of the cleft defect did not correlate with the success rate of the alveolar bone grafting. The form of the transplant remained almost constant when the permanent canine erupted spontaneously into the graft. In cases of absence of the permanent tooth or when the permanent canine required orthodontic treatment, significant bone loss could be observed in the buccopalatal direction.** Conclusion: **Three-dimensional reconstruction of bone grafts using a navigation system enables a valuable objective assessment of graft volume. Bone formation can be assessed in all three dimensions showing a high grade of resorption in patients lacking physiological load.** © **2006 European Association for Cranio-Maxillofacial Surgery**

Keywords: **alveolar bone grafting; radiographic assessment; navigation system**

INTRODUCTION

Bone grafting is an essential step in the overall management of patients with clefts of lip, alveolus and palate. Although no one questions the need for alveolar cleft repair, controversy still exists regarding the timing of the surgical intervention.

The two most common options regarding the timing of bone grafting are ‘primary’ bone grafting in infancy at about the time of initial surgical lip repair (*Schuchardt*, 1966; *Rosenstein* et al., 1982) and ‘secondary’ alveolar bone grafting in the mixed dentition first described by *Boyne* and *Sands* (1972).

Secondary alveolar bone grafting has become accepted as a means of uniting and stabilizing the segments of the maxilla prior to definitive orthodontic and restorative dental treatment (*Enemark* et al., 1985). To allow spontaneous eruption of the adjacent teeth and to improve craniofacial development, this technique should ideally be performed during the mixed dentition phase (*Bergland* et al., 1986; *Brattstrom* et al., 1992).

The bone used most commonly include iliac crest (*Boyne* and *Sands*, 1972), calvarial (*Wolfe* and *Berkowitz*, 1983; *Tessier*, 1992), rib (*Rosenstein*, 1963; *Rosenstein* et al., 1982, 1991) or tibia (*Kalaaji* et al., 2001). Regardless of the donor site, cancellous bone is preferable to cortical or osteochondral grafts (*Borstlap* et al., 1990).

Various methods have been employed to determine success related to providing bone support for teeth adjacent to the cleft. Most authors rely on intraoral radiography and clinical examination for assessing the cleft, both pre- and postgrafting (*Kindelan* et al., 1997; *Aurouze* et al., 2000; *Lilja* et al., 2000; *Newlands*, 2000; *Dempf* et al., 2002). Therefore, radiographic indices of graft integration have been developed by several authors (*Åbyholm* et al., 1981; *Helms* et al., 1987; *Brattstrom* and *McWilliam*, 1989; *Amanat* and *Langdon*, 1991).

Although bone remodelling and two-dimensional changes can be evaluated by conventional radiographs to a certain extent, the failure to assess the changes in volume, morphology and bony architecture are disadvantages inherent within this method.

More recently computed tomography has been used by *Rosenstein* et al. (1997) and *Van der Meij* et al. (2001) to evaluate bone grafts. But the change of bone volume has not been evaluated *longitudinally*.

The purpose of this study was to evaluate the outcome of alveolar bone grafting by estimating volumes immediately preoperatively and 1 year postoperatively.

For this purpose a CT-based three-dimensional navigation system was used, in which the three-dimensional software enabled visualization of the bone transplant three dimensionally on the workstation.

PATIENTS AND METHODS

In this prospective study, 16 patients with complete UCLAP were examined (9 female, 7 male) representing an average Caucasian cleft population.

Treatment history

All patients had been treated by a two-step surgical technique of cleft repair. The lip had been closed between the 3rd and 6th month of life according to the technique of *Millard* (1957). The hard and soft palate had been closed between the 12th and 29th month of life by a pedicled flap according to Veau as described by *Berndorfer* (1969).

All patients had undergone bone grafting with particulate cancellous bone and marrow taken from the anterior iliac crest. The surgical approach to the unilateral alveolar cleft and mucosal flap repair was performed using the lateral sliding flap described by *Boyne* and *Sands* (1972; also by *Hall* and *Werther* 1991). The age range of the patients at surgery was between 9 years 2 months and 14 years 11 months (mean 10 years 6 months). All operations were performed by a single maxillofacial surgeon. No patient underwent concomitant orthognathic procedures.

Scan protocol

Computed tomography (CT) scans were taken immediately preoperatively and 1 year postoperatively.

Each patient had a computerized axial tomograph taken of the skull. Patient positioning was standardized with the maxillary alveolar crest parallel to the plane of the scan. Slices of 1.5 mm were taken from the nasal cavity to the occlusal plane. The mean cerebral radiation dose was calculated as 7.88 mSv.

Reformatting

All images from the CT scans were loaded onto a computer workstation (STN-Zeiss-Navigation System, Aalen, Germany) for volumetric analysis. The STN-operator console contained the proprietary software (stereotactic treatment planning system STP version 3.3 ×, Howmedica Leibinger GmbH Freiburg, Germany) that enabled the volumetric analysis to be performed directly on the CT scan images.

Measurements and reformatting were performed by a single operator to eliminate interoperator viability.

The alveolar cleft defect and the transplanted iliac crest bone were outlined on each slice (Fig. 1). The ‘volume’ command in the STN-Zeiss-Navigation workstation was then used to determine the actual volume of the region of interest. This procedure was repeated three times on every patient to avoid mistakes in outlining the region of interest.

Scan data were reformatted into three-dimensional images that demonstrated the structures of interest. Three-dimensional viewing provided the advantage of assessing the overall positioning, size and spatial relationships of the area. Particular care was taken to assess (1) evidence of bone bridging between the alveolar segments, (2) status of the adjacent teeth, and (3) the quality of bone 1 year postoperatively.

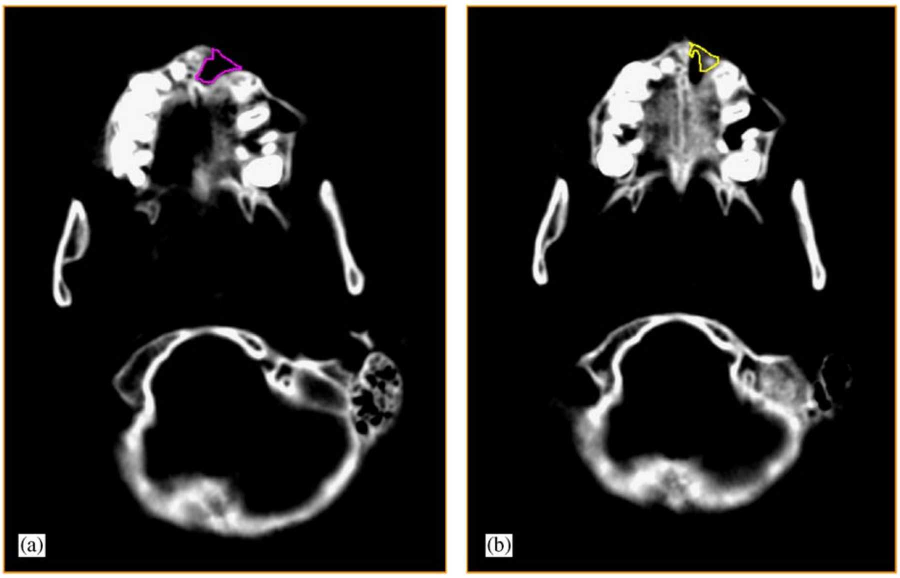

Fig. 1 – a, CT scan before bone grafting, b, at 1 year after bone grafting. The tracings depict the areas measured.