Placement of Endosseous Implants Into Bone-Grafted Alveolar Clefts: Assessment of Bone Bridge After Autogenous Particulate Cancellous Bone and Marrow Graft

Tetsu Takahashi, DDS, PhD*/Masayuki Fukuda, DDS, PhD**/
Tai Yamaguchi, DDS, PhD***/Shoko Kochi, DDS, PhD****

The objective of this study was to evaluate the bone quantity of alveoli grafted with autogenous particulate cancellous bone and marrow for implant placement in patients with alveolar clefts. Bone height, bone width, and interdental alveolar crest level were evaluated using computed tomography and periapical radiographs. The grafted alveoli underwent resorption 3-dimensionally, and the interdental alveolar crest level also decreased. The latter seemed to be the critical factor for implant surgery, as almost half of the grafted alveoli required another bone graft within 24 months after the original bone graft to increase the interdental alveolar crest level for endosseous implant placement. These data suggest that alveoli grafted with particulate cancellous bone and marrow are suitable for implant placement, but that the loss of width and height of the bone bridge must also be considered.
(INT J ORAL MAXILLOFAC IMPLANTS 1999;14:86–93)

Key words: bone bridge, bone graft, cleft lip or palate, grafted alveolar cleft, interdental alveolar bone height, particulate cancellous bone and marrow

The presence of an alveolar cleft is one of the major obstacles to good dental arch morphology in patients with cleft lip and/or palate (CLP). In 1972, Boyne and Sands introduced secondary autogenous particulate cancellous bone and marrow (PCBM) grafting for the treatment of alveolar and residual palatal clefts.[1] Our protocol for the dental reconstruction of patients with CLP is to perform bone grafting (BG) before canine eruption and subsequent orthodontic closure of the dental arch without using prostheses, as described in previous reports.[2–4] However, because of the excessively long treatment period or a wide interdental space resulting from several congenitally missing teeth, prosthetic treatment is sometimes necessary. In such patients, endosseous implants are placed in bone-grafted alveoli after repair of the alveolar cleft by secondary BG using PCBM.[5,6]

Although there are a number of reports regarding the combination of autogenous PCBM bone grafts with implant placement in the maxilla, nasal fossa and maxillary sinus,[7–11] no clinical data are available regarding the assessment of grafted alveolar clefts for implant placement. The objectives of this study were to evaluate the bone bridge 3-dimensionally after PCBM grafting and to determine whether grafted alveoli are suitable for implant placement.

*Lecturer, Division of Oral and Maxillofacial Surgery, Akita University School of Medicine, Akita, Japan.
**Assistant Professor, Division of Oral and Maxillofacial Surgery, Akita University School of Medicine, Akita, Japan.
***Director, Department of Dentistry and Oral Surgery, National Sendai Hospital, Sendai, Japan.
****Associate Professor, Clinic for Maxillo-Oral Disorders, Tohoku University School of Dentistry, Sendai, Japan.

Reprint requests: Dr Tetsu Takahashi, Division of Oral and Maxillofacial Surgery, Akita University School of Medicine, 1-1-1 Hondo Akita City, Akita 010, Japan. Fax: +81-18-884-6451. E-mail: tetsu@akita-u.ac.jp

Table 1 Demographic and Clinical Characteristics of Patients with Endosseous Implants

Patient no.	Sex	Cleft type	Age at bone grafting (y)	Duration of bone formation (y)	IACL (score)	Bone quality* (class)	Implant length (mm)
1	F	UCLP	9.8	10.2	2**	3	15
2	F	UCLP	11.4	7.2	2	2	15
3	F	UCLP	11.8	6.7	2**	3	13
4	F	UCLA	11.8	6.5	2**	3	15
5	F	UCLP	14.8	6.3	2	4	10
6	F	UCLA	13.4	4.3	2**	3	15
7	M	UCLP	15.2	2.6	2	3	15
8	F	UCLP	10.3	6.8	3	3	15
9	F	UCLP	14.9	3.1	3	4	13
10	M	UCLP	31.7	1.9	3	3	13
11	M	BCLP	8.8	6.2	4	4	15,18
12	F	UCLA	9.7	5.1	4	3	15
13	M	UCLP	14.4	3.8	4	3	13
14	M	UCLP	12.5	3	4	3	15

*Bone quality was ranked into 4 grades based on the classification of Lekholm and Zarb.[12]
**Chin bone onlay grafting was performed at implant placement.
UCLP = unilateral cleft lip and palate; UCLA = unilateral cleft lip and alveolus; BCLP = bilateral cleft lip and palate; IACL = interdental alveolar crest level.

Materials and Methods

Subjects. The subjects were all patients with CLP under care at the Clinic for Maxillo-Oral Disorders, Tohoku University Dental Hospital, Sendai, Japan. Ninety-three patients (42 male and 51 female) with 101 alveolar clefts were enrolled in this study. These patients had undergone secondary BG with PCBM from the iliac crest at the Department of Oral and Maxillofacial Surgery, Tohoku University Dental Hospital, followed by orthodontic treatment. Their mean age at the time of secondary BG with PCBM was 11.0 years (range, 7.6 to 31.7 years).

Fourteen patients with CLP, in whom endosseous implants were placed into grafted alveoli and in whom these grafted alveoli could be evaluated by computed tomography (CT) and periapical radiographs before and after implant placement, were also included (Table 1). Most of these patients were initially scheduled to receive a prosthesis, such as a conventional denture or a partial prosthesis, and not to be treated with implants. These 14 patients underwent placement of Brånemark implants (Nobel Biocare AB, Göteborg, Sweden) between February 1993 and December 1994. Their mean age at the time of secondary BG with PCBM was 13.6 years (range, 8.8 to 31.7 years) and their age at the time of implant placement was 18.9 years (range, 15.0 to 33.6 years). The mean duration from PCBM grafting to implant placement was 5.3 years. The follow-up period ranged from 2 years to 4 years after implant placement (mean period, 3.3 years). These implants were all osseointegrated and the clinical outcome was uneventful.

Bone Formation Evaluated by Computed Tomography and Periapical Radiographs. Axial CT scans were acquired using a slice thickness of 2 mm (Figs 1 and 2). These scans were obtained parallel to a line that included the anterior nasal spine (ANS) and porion (PO) extending from the alveolar edge of the maxillary central incisor to the nasal cavity. Seven to 10 of the slices, including the BG itself, were acquired using this scanning procedure for each patient. A magnification factor was indicated and registered on all scans. This scanning procedure was designed primarily for evaluation of the BG, not for evaluation of endosseous implant placement. Periapical radiographs were usually obtained before BG; 1, 3, and 6 months after BG; and annually beginning at 12 months (up to 72 months).

Estimation of Bone Height and Bone Width. The height of the bone bridge after PCBM grafting in the alveolar cleft was estimated and evaluated in a time course study. The width was calculated by direct measurement of an axial image. The height was calculated by summation over the length in which the grafted alveoli appeared in an axial image and was trigonometrically corrected to the inclination of the maxillary incisors (Fig 3). The available height of the bone bridge for implant placement was then calculated by summation over the length on an axial image more than 4 mm from the crest (Fig 3). The diameter of the Brånemark implants used was taken into consideration when calculating bone bridge height.

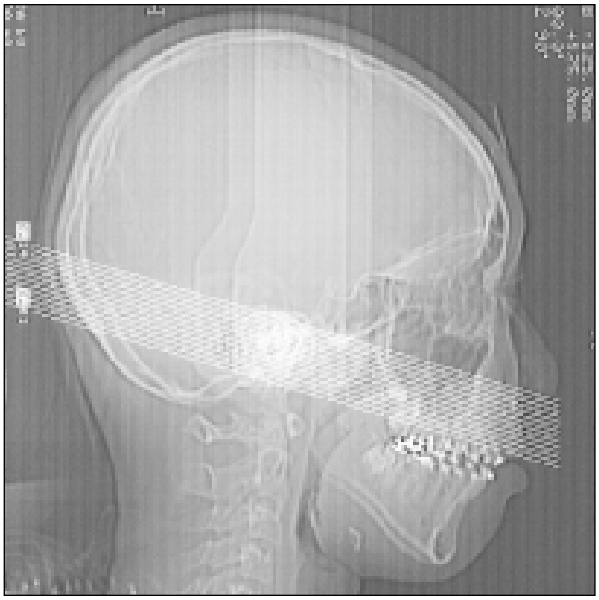

Fig 1 Axial CT scanning of grafted alveoli.

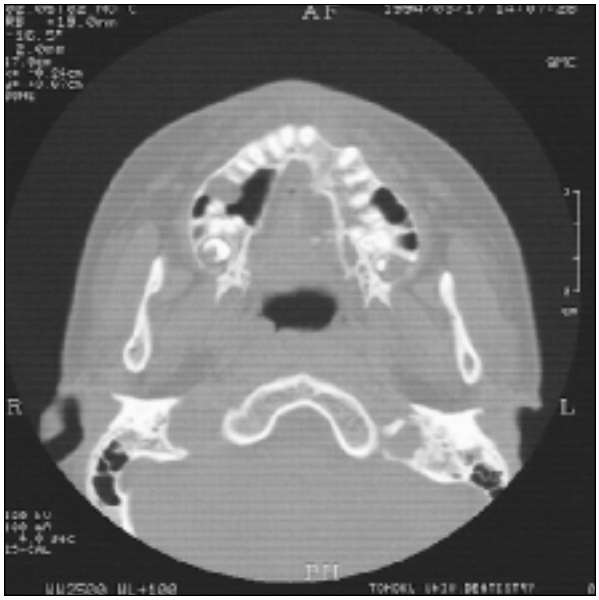

Fig 2 The alveolar bone width was measured using an axial CT image.

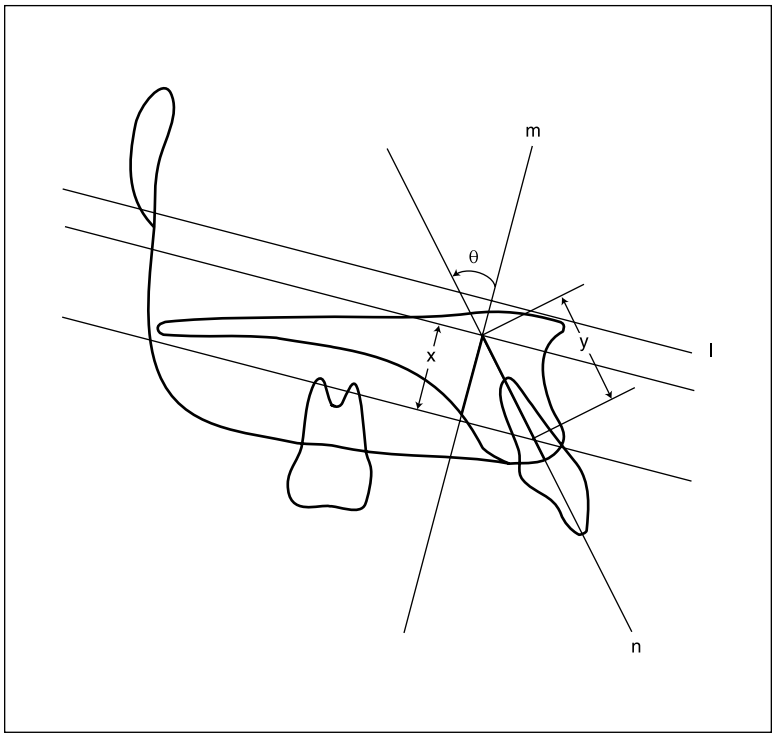

Fig 3 The alveolar bone height was calculated using axial CT images and trigonometrically corrected to the inclination of other incisors. X = the value of the measurement by summation of slice width of each axial image in which the grafted alveoli appeared (assuming that the grafted alveoli appeared over image 1 to image 5, X is calculated at 10 mm). Y = the value of the net alveolar bone height, trigonometrically corrected; $X^{\prime}$ = the value of the length with vertical height of more than 4 mm; $Y^{\prime}$ = the value of the available alveolar bone height trigonometrically corrected; l = the base line (Po-ANS); m = the line crossing l at right angles; θ = an angle between base line n and m. Net alveolar bone height (Y) equaled X divided by cosθ. Available alveolar bone height (Y') equaled X' divided by cosθ.

Estimation of Interdental Alveolar Crest Level. The interdental alveolar crest level (IACL) was estimated and scored using periapical radiographs, as previously reported.[5] The lowest part of the outline of the interdental alveolar crest was estimated and scored as shown in Fig 4. Thirty-eight grafted alveoli in 33 consecutive patients who could be followed up at least 24 months were enrolled in the time course study.

Estimation of Available Grafted Alveoli for Implant Placement. The frequency of grafted alveoli whose bone volume, as well as IACL, were suitable for implant placement in 38 grafted alveoli and could be concurrently evaluated by CT and periapical radiographs was determined. It was assumed that implants greater than 10 mm in length would be used and the optimal interdental alveolar bone height score was 3 or 4.

Statistical Analysis. The mean value of bone height and alveolar bone width was calculated, and the value 1 month after PCBM was compared with that at 6 to 24 months, 25 to 60 months, and more than 60 months after PCBM using unpaired *t* test. The relationship between the duration from BG and implant placement and bone height and bone width was analyzed using Pearson's correlation coefficient. The proportion of grafted alveoli suitable for implant placement 24 months before and after PCBM was analyzed using the chi square test. For all tests, a *P* value of .05 was considered significant.

Results

Bone Height and Alveolar Bone Width. Results of the time course study after PCBM grafting are shown in Table 2. The mean net bone height 1 month after BG was approximately 17 mm. Although there was no significant loss of the net bone height, the proportion of bone more than 4 mm wide gradually decreased. Available bone height at 1 month after PCBM grafting was significantly greater than that at 6 to 24 months, 25 to 60 months, and more than 60 months after BG. This decrease in available bone height seemed to be the result of loss of alveolar bone width. The mean value of the minimal and the mean bone width, compared to that at 1 month after BG, was significantly decreased even at 6 months after BG. The mean alveolar bone width at more than 60 months after BG (6.6 mm) was only about half of that 1 month after BG (12.9 mm). Although the mean value of maximal alveolar bone width 6 months after BG (15.2 mm) was not significantly different from that 1 month after BG (17.8 mm), it had decreased significantly by 24 months after BG (11.2 mm). The mean minimal alveolar bone width at more than 24 months after BG was less than 4 mm, which suggests that some grafted alveoli had insufficient width for implant placement after 24 months. Nonetheless, mean available bone height was 13.4 mm, which seemed to be sufficient for implant placement, even more than 5 years (60 months) after BG.

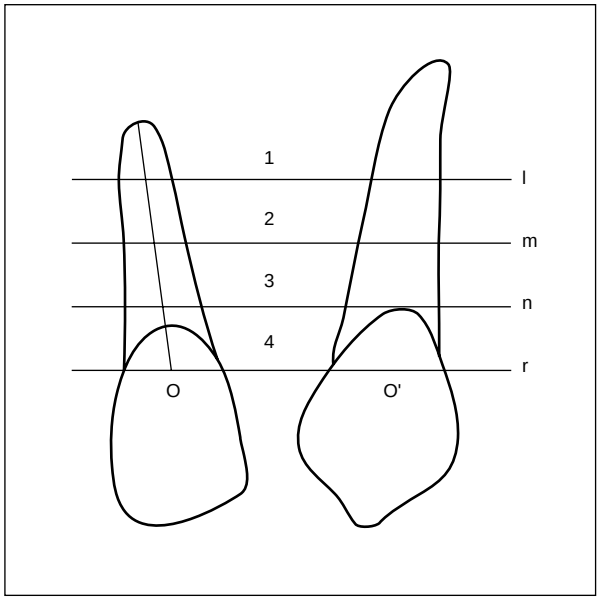

Fig 4 Evaluation of IACL. The outline of the interdental crestal bone level is situated: Score 4: between lines r and n; Score 3: between lines n and m; Score 2: between lines m and l; Score 1: lower than line l.

Table 2 Evaluation of Bone Bridge after Bone Grafting with PCBM

Duration from BG to implant placement (mo)	No. of alveoli examined	Alveolar bone height		Alveolar bone width		
		Net (mm)	Available (mm)	Maximal (mm)	Minimal (mm)	Mean (mm)
1	52	17.4 ± 2.2	17.3 ± 2.1	17.8 ± 4.7	7.4 ± 2.6	12.9 ± 2.3
6–24	17	15.0 ± 3.9	13.6 ± 4.7***	15.2 ± 5.5	5.2 ± 2.1**	10.9 ± 4.2*
25–60	12	16.9 ± 4.3	14.4 ± 5.7**	11.2 ± 4.1**	3.3 ± 1.6***	7.5 ± 2.6***
> 60	20	18.3 ± 4.3	13.4 ± 4.4***	9.6 ± 3.1**	2.9 ± 1.6***	6.6 ± 2.5***

*$P < .05$; **$P < .01$; ***$P < .001$.

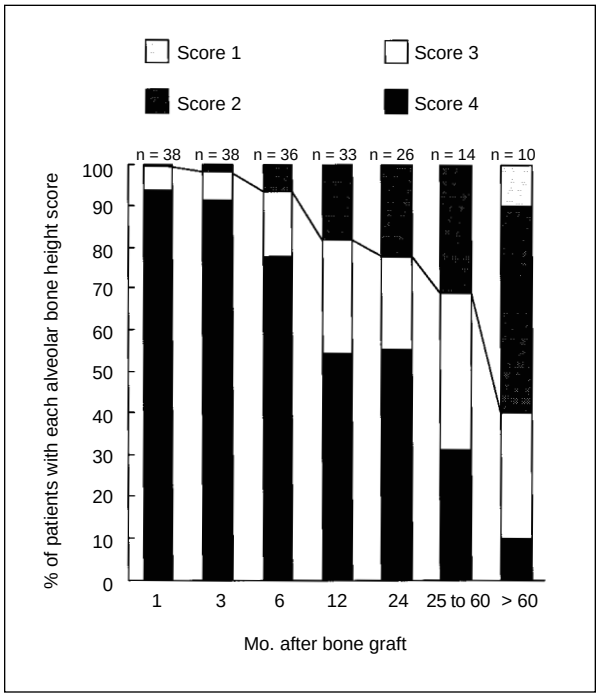

Fig 5 Graph indicating loss of interdental alveolar bone height over the course of the study.

Relationship between Duration from PCBM Bone Grafting to Implant Placement, Bone Height, and Bone Width. Because time after PCBM grafting seems to be a factor affecting the value of both bone height and bone width, we next investigated the relationship between the duration from PCBM bone grafting to implant placement and the value of bone height and bone width (Table 3). There was a significant inverse correlation between duration and alveolar bone width. Although there was also a weak and inverse correlation between duration and available bone height, there was no correlation between duration and net bone height.

Evaluation of Interdental Alveolar Crest Level. The time course study of IACL revealed that more than 80% of grafted alveoli had an IACL score of 4 within 6 months after BG. However, after 24 months, the proportion of the grafted alveoli with a score of 4 had decreased to one-third. The proportion of alveoli with a score of 3 or 4, which is usually suitable for implant placement (no additional grafting is needed), was more than 90% within 6 months after BG, but it decreased to approximately 40% by 5 years after BG (Fig 5).

Available Grafted Alveoli for Implant Placement. Because IACL greatly decreased after 24 months, which suggests that some grafted alveoli had insufficient width for implant placement after 24 months, available grafted alveoli for implant

Table 3 Relationship between Duration from BG to Implant Placement, Bone Height, and Bone Width

	Pearson's correlation coefficient	
	R	*P*
Duration versus bone width		
Maximal	–.515	< .0001
Minimal	–.618	< .0001
Mean	–.677	< .0001
Duration versus bone height		
Net	.086	.4086
Available	–.368	.0002

Table 4 No. of PCBM-Grafted Alveoli Suitable for Implant Placement

Duration from BG to implant placement (mo)	Frequency of sufficient bone bridge		
	Volume	Height	Gross†
≤ 24	13/15 (87%)	14/15 (93%)	12/15 (80%)
> 24	17/23 (74%)	14/23 (61%)	10/23 (44%)*
Mean	30/38 (79%)	28/38 (74%)	22/38 (58%)

*$P < .05$.
†Available grafted alveoli that have sufficient volume as well as acceptable IACL (3 or 4 score).

placement at 24 months before and after BG was estimated. Within 24 months after BG, 87% and 93%, respectively, of the grafted alveoli showed an IACL score of 3 or 4 and acceptable volume. However, at more than 24 months after BG, the grafted alveoli showed decreased volume and height. Of the grafted alveoli, 44% and 80% were suitable for implant placement at more than 24 months after BG and at 6 to 24 months after BG, respectively. There was a significant decrease in the proportion of bone bridges suitable for implant placement 2 years after BG ($P < .05$) (Table 4).

Discussion

The dental rehabilitation of patients with an alveolar cleft is challenging for the clinician because the congenital bone defect is combined with congenitally missing teeth or tooth anomalies, mostly in the lateral incisor region. In addition, malocclusions and dentofacial deformities are frequently seen in these patients. Currently, orthodontic and nonprosthodontic treatment combined with secondary BG with PCBM seems to be acceptable for the dental rehabilitation of patients with an alveolar cleft.[1–4] However, some patients still need conventional dentures or partial prostheses.

The use of endosseous implants placed into alveoli after PCBM grafting seems to be a viable option for dental rehabilitation of patients with alveolar clefts and congenitally missing teeth. Since 1993, this method for dental reconstruction in patients with CLP has been used at our institution. The overall survival rate of implants in grafted alveoli has been 90.5%, and the clinical short-term outcome (1 year to almost 3 years) was very promising, as indicated in a preliminary report.[5] However, questions arose as to how frequently these grafted alveolar clefts could be used for implant placement and as to the optimal timing of secondary BG and implant placement. Although secondary BG of alveolar clefts is a well-established procedure,[1–4] clinical data are lacking for the delayed placement of endosseous implants into the grafted region after PCBM grafting.

The evaluation of BG in patients with CLP using CT has also been established.[13] Computed tomography has been used for the evaluation of bone bridge formation after PCBM grafting for subsequent orthodontic treatment.[14] In this study, CT was used for the evaluation of bone quantity for implant placement. Because a scanning procedure was not planned for preoperative assessment for implant surgery, only axial CT scans were available to evaluate both bone width and bone height. Therefore, it should be pointed out that one limitation of this study is the method of estimating bone height. Theoretically, an error between 2 and 4 mm may be taken into consideration for the estimation of bone height using this method.[15] Nonetheless, the estimation of bone height using axial CT scans has been shown to be useful for the presurgical estimation of the height and width of grafted alveoli.[15] CT scanning with multiplanar reformations enables true cross-sectional scanning of the maxilla[16] and can provide a more accurate estimate of alveolar bone height.

It was found that the grafted bone underwent resorption 3-dimensionally. Time course study of bone height, bone width, and IACL after PCBM grafting revealed that the resorption of grafted bone was greater in width than in height, especially at the crestal region. By 24 months after BG, the mean minimal alveolar bone width was less than 4 mm. This change, together with the loss of IACL, could make the placement of implants in grafted alveoli difficult.

The available bone height was then calculated on the assumption that the implant diameter was less than 4 mm because the diameter of the Brånemark implants used in this study was 3.75 mm. Although the available bone height significantly and progressively decreased, the mean available bone height was more than 13 mm, even after 5 years. This suggests that PCBM-grafted alveoli are suitable for implant placement over quite a long period, since an implant at least 10 mm in length should be enough for implants intended to replace lateral incisors.[5]

Although the grafted alveoli showed adequate bone volume horizontally and vertically, an insufficient IACL prevents proper implant placement. Use of implants in alveoli with insufficient IACL will not result in an appropriate suprastructure–implant length ratio. In addition, an excessively long artificial tooth is not esthetically acceptable. Previous studies have suggested that the IACL is insufficient for implant placement if there is a long wait between the time of BG and the time of implant placement.[5,17] In these patients, another graft may be needed to augment the IACL before implant placement. Therefore, the IACL seems to be a critical factor, and thus bone with a class 3 or class 4 height is recommended for implant placement.

In this study, the IACL was significantly decreased 24 months after BG. Whereas delayed implant placement seemed to be possible in most grafted alveoli (80%) within 2 years of BG, less than half of the grafted alveoli (44%) were suitable for implant placement after more than 2 years. Although it is beyond the scope of this study to elu-

cidate the optimal timing of BG and implant placement in patients with alveolar clefts, one could speculate that implant placement should not be delayed beyond 2 years after BG, given these findings.

The IACL seemed to be influenced not only by the time lag between BG and implant placement, but also by patient's age at the time of BG. It is well accepted that secondary BG of alveolar clefts in patients with CLP should be performed before canine eruption.[18–20] The reasons for this are the better clinical results seen in younger individuals[21,22] and the greater osteogeneic activity in younger than in older patients.[23] Although it was not statistically significant, there was a tendency to an inverse correlation between alveolar bone height and age at the time of BG in this study (data not shown). Therefore, from a clinical point of view, secondary BG for alveolar clefts should be performed when the patient is young. Even if BG is performed at a younger age, the placement of implants in adolescence is not recommended because the implant behaves like an ankylosed tooth and becomes submerged as the surrounding bone grows.[24,25] Other factors such as the width of the alveolar cleft,[26] the presence of mucobuccal or mucolabial flaps,[27] shortage of soft tissue,[18] and oral hygiene[21] also seem to have an effect on IACL.

In addition, the orthodontic treatment period includes the healing time of grafted alveoli before orthodontic treatment (usually 6 months), the period of teeth alignment (at least 1 year), and the period for retention required before placing implants. Grafted alveoli might therefore undergo bone resorption during the orthodontic treatment period. The loss of alveolar bone volume and IACL seen in this study may be related to the orthodontic treatment procedures used.

It should be pointed out that this study was cross-sectional in terms of evaluating the width and height of the grafted alveoli. Therefore, care should be taken to interpret the findings and their full implications. Further well-designed, longitudinal studies will be required before the optimal timing for delayed implant placement into grafted alveoli can be determined.

Summary

It is encouraging to confirm that grafted alveoli seem to retain sufficient bone quantity over a long period after BG with PCBM. This suggests that grafted alveoli are durable and suitable for implant placement. The question arises as to how to avoid or to manage the loss of IACL. Therapeutically, an interdental bone augmentation technique using chin bone grafting or guided bone regeneration[28,29] at implant placement[8] can be beneficial. However, further intensive studies should focus on determining the optimal timing for secondary BG of alveolar clefts and on elucidating the treatment management, including orthodontic treatment procedures involving the grafted alveoli, that results in minimal bone loss before implant placement.

Acknowledgments

The authors thank Dr Makoto Watanabe, DDS, PhD, Professor and Chairman, Department of Geriatric Dentistry; Dr Tetsuji Inai, DDS, PhD, Lecturer, Department of Prosthetics II; and Dr Keiko Yamaki, DDS, PhD, Assistant Professor, Department of Endodontics; all at Tohoku University School of Dentistry, Sendai, Japan, for their contributions to this project and their treatment of the patients.

References

1. Boyne PJ, Sands NR. Secondary bone grafting of residual alveolar and palatal clefts. J Oral Surg 1972;30:87–96.
2. Kochi S, Teshima T. Bone grafts in the alveolar cleft using autogenous particulate marrow and cancellous bone: Successful bone formation and related factors. Dent Jpn 1994;31:62–66.
3. Åbyholm FE, Bergland O, Semb G. Secondary bone grafting of alveolar clefts: Surgical/orthodontic treatment enabling a non-prosthodontic rehabilitation in cleft lip and palate patients. Scand J Plast Reconstr Surg 1981;15:127–140.
4. Bergland O, Semb G, Åbyholm FE. Elimination of the residual alveolar cleft by secondary bone grafting and subsequent orthodontic treatment. Cleft Palate J 1986;23:175–205.
5. Takahashi T, Fukuda M, Yamaguchi T, Kochi S. Use of endosseous implants for dental reconstruction of patients with grafted alveolar clefts. J Oral Maxillofac Surg 1997;55:576–583.
6. Takahashi T, Fukuda M, Yamaguchi T, Kochi S, Matsui K, Echigo S, et al. Use of osseointegrated implants to the cleft lip and/or palate patients—Placement of Brånemark implant to the grafted alveolus [in Japanese]. J Jpn Stomatol Soc 1995;44:399–407.
7. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980; 38:613–616.
8. Breine U, Brånemark P-I. Reconstruction of alveolar jaw bone. An experimental and clinical study of immediate and preformed autologous bone grafts in combination with osseointegrated implants. Scand J Plast Reconstr Surg 1980;14:23–48.
9. Jensen J, Sindet-Pedersen S. Autogenous mandibular bone grafts and osseointegrated implants for reconstruction of the severely atrophied maxilla: A preliminary report. J Oral Maxillofac Surg 1991;49:1277–1287.

10. Jensen J, Sindet-Pedersen S. Varying treatment strategies for reconstruction of maxillary atrophy with implants: Results in 98 patients. J Oral Maxillofac Surg 1994;52:210–216.
11. Kent JN, Block MS. Simultaneous maxillary sinus floor bone grafting and placement of hydroxyapatite-coated implants. J Oral Maxillofac Surg 1989;47:238–242.
12. Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
13. Van der Meji, Baart JA, Prahl-Andersen B, Balk J, Kostense PJ, Tuinzing DB. Computed tomography in evaluation of early secondary bone grafting. Int J Oral Maxillofac Surg 1994;23:132–136.
14. Iino M, Kochi S, Matsui K, Tamaki Y, Takahashi T, Yamaguchi T, et al. Secondary bone grafting of alveolar clefts using autogenous particulate cancellous bone and marrow harvested from iliac bone—Evaluation of the bone bridging by means of x-ray computed tomography [in Japanese]. J Jpn Cleft Palate Assoc 1994;19:22–31.
15. Takahashi T, Fukuda M, Yamaguchi T, Kochi S, Inai T, Watanabe M, et al. Application of osseointegrated implants to bone-grafted regions in cleft lip and/or palate patients: Presurgical assessment of grafted alveoli for the placement of osseointegrated implants [in Japanese]. Tohoku Univ Dent J 1995;14:103–110.
16. Rothman SLG, Chaftez N, Rhodes ML, Schwartz MS. CT in the preoperative assessment of the mandible and maxilla for endosseous implant surgery. Radiology 1988;168:171–175.
17. Takahashi T, Fukuda M, Kochi S, Yamaguchi T, Nagai H, Takano H, et al. Application of osseointegrated implants to the grafted alveoli of patients with cleft lip and/or palate—Evaluation of bone bridge formation for placement of osseointegrated implant [in Japanese]. J Jpn Stomatol Soc 1996;45:470–478.
18. Sindet-Pedersen S, Enemark H. Comparative study of secondary and late secondary bone-grafting in patients with residual clefts. Short-term evaluation. Int J Oral Surg 1985;14:389–398.
19. Enemark H, Sindet-Pedersen S, Bundgaard N. Long-term results after secondary bone grafting of alveolar clefts. J Oral Maxillofac Surg 1985;45:913–919.
20. Bergland O, Semb G, Åbyholm F, Borchgrebink H, Eskeland G. Secondary bone grafting and orthodontic treatment in patients with bilateral complete clefts of the lip and palate. Ann Plastic Surg 1986;17:460–474.
21. Ames J, Doran ER, Maki KA. The autogenous particulate cancellous bone marrow graft in alveolar clefts. A report of forty-one cases. Oral Surg Oral Med Oral Pathol 1981;51:588–591.
22. Turvey TA, Vig K, Moriarty J, Hoke J. Delayed bone grafting in the cleft maxilla and palate: A retrospective multidisciplinary analysis. Am J Orthod 1984;86:244–256.
23. Jowsey J. Age changes in human bone. Clin Orthop 1960;17:210–218.
24. Lekholm U. The use of osseointegrated implants in growing jaws. Int J Oral Maxillofac Implants 1993;8:243–244.
25. Westwood RM, Duncan JM. Implants in adolescents: A literature review and case reports. Int J Oral Maxillofac Implants 1996;11:750–755.
26. Kochi S, Toufukuji, Matsui K, Nagajima H, Takahashi T, Teshima T. Bone graft in alveolar cleft with autogenous particulate cancellous bone: Evaluation of interdental alveolar bone height. Jpn J Oral Maxillofac Surg 1993;39:735–741.
27. Enemark H, Krants-Simonsen E, Shramm JE. Secondary bone grafting in unilateral cleft lip palate patients: Indications and treatment procedure. Int J Oral Surg 1985;14:2–10.
28. Buser D, Brägger U, Lang NP, Nyman S. Regeneration and enlargement of jaw bone using guided tissue regeneration. Clin Oral Implants Res 1990;1:22–32.
29. Becker W, Dahlin C, Becker BE, Lekholm U, van Steenberghe D, Higuchi K, et al. The use of e-PTFE barrier membranes for bone promotion around titanium implants placed into extraction sockets: A prospective multicenter study. Int J Oral Maxillofac Implants 1994;9:31–40.