Alveolar Ridge Reconstruction with Titanium Mesh and Autogenous Particulate Bone Graft: Computed Tomography-Based Evaluations of Augmented Bone Quality and Quantity

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ABSTRACT

Purpose: The purpose of this study was to evaluate the quality and quantity of augmented bone following alveolar ridge reconstruction with titanium mesh and autogenous particulate bone graft for implant placement in terms of the preoperative bone defect.

Materials and Methods: Forty-one patients (50 sites) rehabilitated between September 2000 and May 2009 with autogenous particulate intraoral bone or iliac cancellous bone marrow grafts and micro-titanium meshes were enrolled. We classified the bone defects by means of shape as complex horizontal–vertical (HV), horizontal (H), and socket (S) types, and the augmented bone was evaluated based on preoperative computed tomographic data. The postsurgical complications were assessed during the healing period and after implant superstructure placement.

Results: The bone defects were successfully augmented using the titanium mesh technique. The HV-type defect was the most difficult to augment (mean horizontal gain, 3.7 ± 2.0 [SD] mm; mean vertical gain, 5.4 ± 3.4 [SD] mm). The mean horizontal gain with the H-type defect was 3.9 ± 1.9 mm. The S-type defect achieved the most efficient bone augmentation (mean horizontal gain, 5.7 ± 1.4 [SD] mm; mean vertical gain, 12.4 ± 3.1 [SD] mm). The major postsurgical complications were mesh exposure, infection, total or partial bone resorption, and temporary neurological disturbances. Implant failure was observed in one case. The HV-type defect showed significantly higher bone resorption ($p < .05$) than the other defect types.

Conclusions: Autogenous bone grafting with titanium mesh allows adequate vertical and horizontal alveolar bone reconstruction both quantitatively and qualitatively for implant placement. However, the clinical outcome of augmentation depends on the type of preoperative bone defect.

KEY WORDS: autogenous bone graft, bone resorption, dental implant, ridge augmentation, titanium mesh

INTRODUCTION

The reconstruction of alveolar ridges for implant placement is still a challenging surgical procedure, especially in the case of extensive vertical and horizontal bone atrophy. If implant stability or appropriate positioning cannot be achieved, alveolar ridge augmentation is needed. Several bone-augmentation techniques have been introduced, of which autogenous bone grafting is

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the "gold standard."[1–5] A major complication of bone grafting is bone resorption. To prevent this complication, some authors have suggested augmentation procedures in conjunction with use of a nonresorbable barrier membrane: the guided bone regeneration (GBR) technique.[6] Autogenous bone grafting with GBR is useful for severe bone resorption.[7] However, animal model studies have indicated that membrane-induced bone does not contribute to implant stability.[8,9] Other researchers have preferred the use of block bone without membranes.[10–12]

The titanium mesh technique is one alternative, based on bone grafting with a stiff occlusive titanium membrane. Roccuzzo and colleagues[13,14] have presented a surgical protocol for vertical ridge augmentation by using autogenous block bone grafts protected by a titanium mesh before implant placement. Reports have indicated that sufficient bone augmentation is achievable, but few studies have used computed tomography (CT)-based data to evaluate vertical and horizontal grafted bone following this technique. Moreover, at the bone defect, vertical bone augmentation is more difficult than horizontal bone augmentation. Clinically, there must be technical indication for the type of bone defect. The aim of this study was to evaluate the quality and quantity of augmented bone following alveolar ridge reconstruction with titanium mesh and autogenous particulate bone graft for implant placement according to the preoperative bone defect by using CT-based data.

MATERIALS AND METHODS

Subjects

Forty-one patients who underwent alveolar ridge reconstruction with particulate bone graft and titanium mesh for implant placement were enrolled in this study. All the patients were treated between September 2000 and May 2009. Fifty bone defect sites were studied in total, including segmental alveolar bone defects because of palatal cleft ($n = 7$ sites), trauma ($n = 5$ sites), cyst ($n = 2$ sites), bone resorption because of peri-implantitis ($n = 2$ sites), and atrophy secondary to tooth loss ($n = 34$ sites). They did not have any particular medical history. All the patients received written information about the surgery and gave written informed consent. Of the 41 patients who underwent reconstruction with particulate bone graft and titanium mesh, 16 were males and 25 were females (mean age = 46.0 years, range = 16–71 years). Fifty sites were treated, with 29 maxillary and 21 mandibular reconstructions. Two patients (three sites) dropped out of the study. Three sites required additional bone-augmentation techniques because of shortage of augmented bone; subsequently, alveolar distraction osteogenesis was performed at two sites and additional bone grafts were placed at one site.

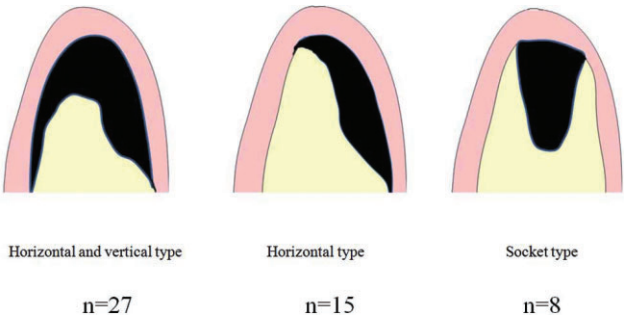

Figure 1 The bone defect types, showing a complex horizontal–vertical defect, horizontal defect, and socket-type defect.

Clinical Procedures

Clinical examinations were performed at the graft donor site, at the reconstruction site, and to determine the type of bone defect. We classified the bone defects according to the shape into three types: complex horizontal–vertical (HV) type ($n = 27$), horizontal (H) type ($n = 15$), and socket (S) type ($n = 8$). Figure 1 shows illustrations of the bone defects classified in this study. CT was performed presurgically; informed consent was obtained again for bone evaluation at the time of the implant placement or mesh removal operation, about 6 months after bone reconstruction ($n = 30$). The obtained data were quantitatively and qualitatively analyzed by using SimPlant Pro version 10 (Columbia Scientific, Inc., Columbia, MD, USA). According to the bone defect type, the horizontal width and vertical height of the augmented bone were analyzed digitally.

Surgical Procedure

During augmentation of the atrophic mandible, a crestal incision was used. All patients underwent mandibular and maxillary reconstruction with autogenous particulate bone grafts obtained from intraoral, mainly mandibular retromolar region ($n = 36$) with a scraper (mx-grafter; Maxilon Laboratories, Inc., Hollis, NH, USA). In the case of iliac crest bone grafts, a curette was used to obtain particulate bone marrow (PCBM, $n = 14$). A staged approach was used for implant installation ($n = 50$). Decortication of the drill holes was

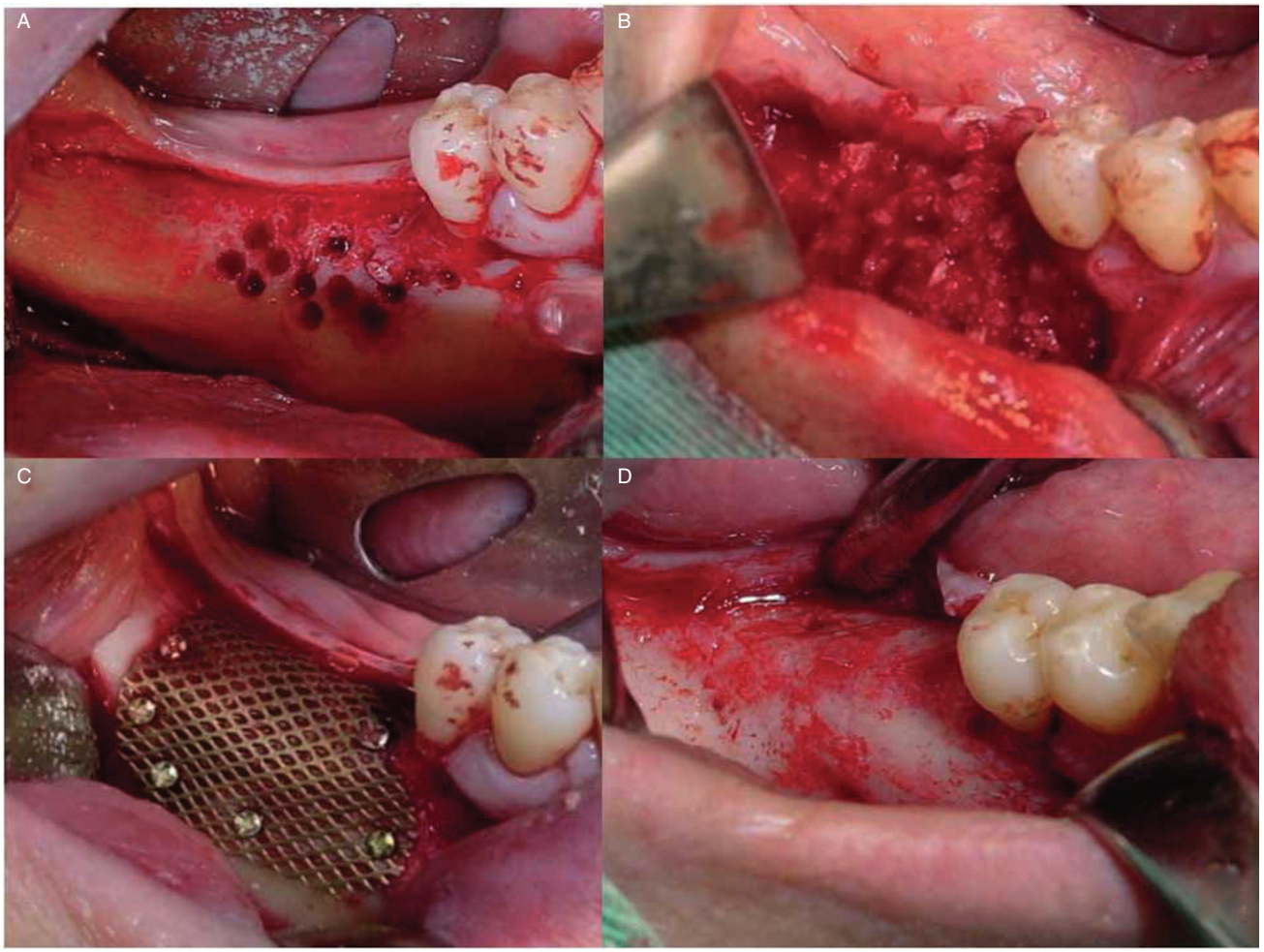

Figure 2 The basic procedure for bone augmentation with titanium mesh and particulate autogenous bone graft. (A) Decortication of the cortical bone, (B) particulate bone graft from the other side of mandibular ramus, (C) titanium mesh placement, and (D) the augmented bone after 6 months from the initial surgery.

performed by using a round burr to ensure vascular nutrition of the grafted bone. Titanium meshes (0.1- or 0.2-mm thickness; M-TAM, Stryker Leibinger GmbH & Co. KG, Freiburg, Germany or ASTM F-67, Jeil Medical Corp., Seoul, Korea) were used according to the shape of the defects. Harvested bone was set on the defects and a shaped titanium mesh was fixed with small titanium screws. With sufficient saline irrigation for a clean surgical field, tension-free 5-0 nylon sutures were placed across the incision on the periosteal membrane above the flap. Photographs of the clinical procedures are shown in Figure 2.

Postsurgical Care

Intravenous antibiotics were administered presurgically. After the operation, symptoms of infection, wound dehiscence, graft loss, and temporary nerve disturbances were evaluated. The problems following prosthesis placement were also evaluated. The postsurgical major complications associated with the type of bone defect were analyzed.

Statistical Analysis

The data were recorded on a personal computer and analyzed with JMP for Windows (version 5.1; SAS Institute, Inc., Cary, NC, USA). Differences in the mean of continuous measurements were tested with Student's *t*-test, analysis of variance (ANOVA), and chi-square test. A p value less than .05 was considered statistically significant. Implant survival rate was estimated using the Kaplan–Meier method.

RESULTS

The success rate of the titanium mesh–bone graft procedure was 88% (44 sites). Nineteen anterior maxillary and 10 posterior maxillary reconstructions as well as

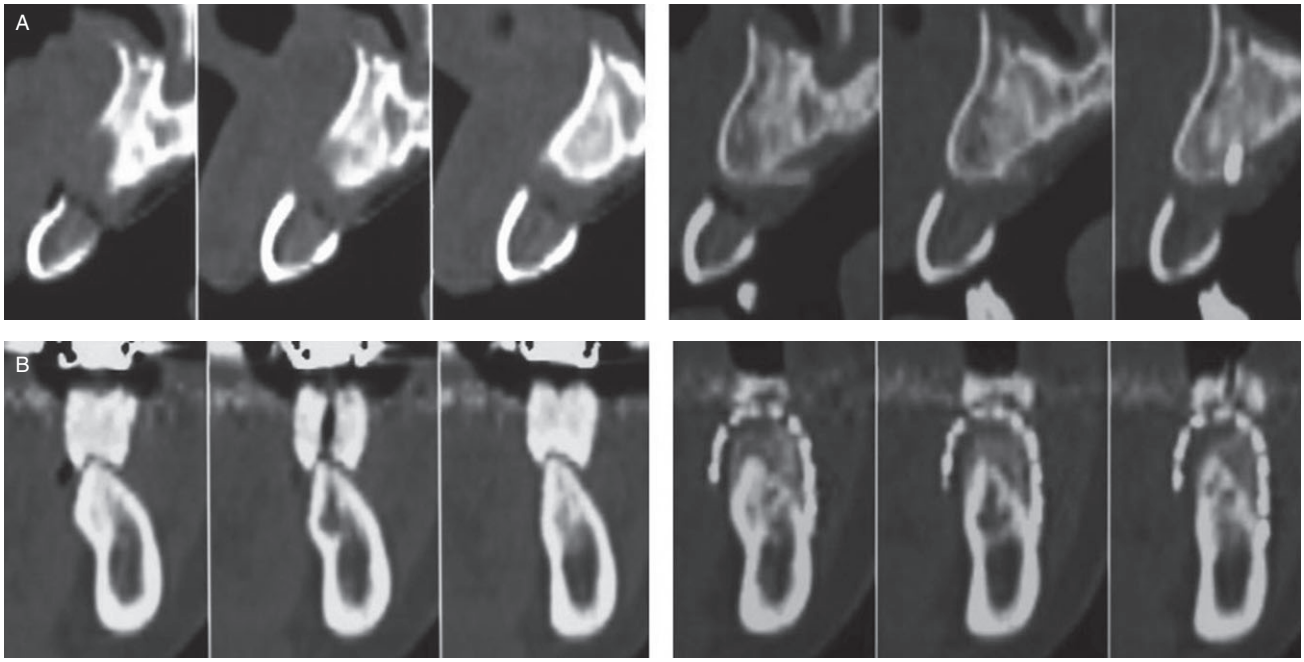

Figure 3 (A) Computed tomography of horizontal–vertical (HV)-type bone defect with particulate bone marrow from iliac crest after 6 months postoperatively. (B) Computed tomography of HV type bone defect with particulated bone graft from mandibular retromolar region shows intended augmented configuration.

two anterior mandibular and 19 posterior mandibular reconstructions were performed. The bone defects were 59% H type in the maxilla and 71% HV type in the mandible. When the titanium meshes were removed, granulation tissue around the titanium meshes without mucosal membrane was observed.

Augmented Bone Evaluation

The bone defects were successfully augmented with titanium mesh and autogenous particulate bone grafts. The typical CT scans of augmented bone were shown in Figure 3, A and B, which represent harvested bone from the iliac crest bone marrow and the mandible. The meshes were removed about 6 months after insertion. According to the available CT data, the bone qualitative evaluations in terms of Hounsfield unit (HU value) were 354 for iliac PCBM ($n = 6$) and 599 for intraoral bone grafts ($n = 16$) at 6 months after the operation. Statistically significant differences were observed between these two groups (Student's t-test: $t = 2.09$, $p < .05$). The HU values for the bone defect types were 545 for the HV type ($n = 8$), 543 for the H type ($n = 10$), and 467 for the S type ($n = 4$). There were no statistically significant differences in this case (ANOVA: $p > .05$). The HU value could not be counted with cone-beam CT data.

The gain of augmented bone was measured digitally. The mean augmented horizontal width was 4.3 ± 2.0 (SD) mm and vertical height was 8.1 ± 4.8 (SD) mm. For the HV-type defects ($n = 13$), the mean horizontal gain was 3.7 ± 2.0 (SD) mm and mean vertical gain was 5.4 ± 3.4 (SD) mm. For the H-type defects ($n = 12$), the mean horizontal gain was 3.9 ± 1.9 (SD) mm. For the S-type defects ($n = 6$), the mean horizontal gain was 5.7 ± 1.4 (SD) mm and mean vertical gain was 12.4 ± 3.1 (SD) mm. The data are shown in Table 1. The results showed a statistically significant difference between the HV and S types in vertical bone gain (Student's t-test: $t = 2.12$, $p < .05$); however, no statistically significant difference was observed in horizontal bone gain (ANOVA: $p > .05$). The HV-type defect was the most difficult type to augment, and the S-type defect had the most efficient bone augmentation.

Postsurgical Course

Several complications were observed after the reconstruction procedure and prosthesis placement, which are listed in Table 2. If wound dehiscence was found within a week, resuturing was performed. The complications after reconstruction were mesh exposure ($n = 18$, 36%), total bone resorption and early removal of mesh because of infection ($n = 4$, 8%), partial bone

TABLE 1 Qualitative and Quantitative Evaluation of (A) Augmented Bone and (B) Bone Defect Type as Well as CT Data on the Mean Gain of the Augmented Bone (C)

(A)			
	Iliac bone ($n = 5$)		Intraoral bone ($n = 16$)
Hounsfield unit	392		596
(B)			
	Horizontal–vertical type ($n = 7$)	Horizontal type ($n = 10$)	Socket type ($n = 4$)
Hounsfield unit	545	509	649
(C)			
	Horizontal–vertical type ($n = 13$)	Horizontal type ($n = 10$)	Socket type ($n = 7$)
Horizontal width	3.7 ± 2.0 mm	3.9 ± 1.9 mm	5.7 ± 1.4 mm
Vertical height	5.4 ± 3.4 mm	–	12.4 ± 3.1 mm

(A) There are statistically significant differences (Student's *t*-test: $p < .05$).
(B) There are no statistically significant differences (Student's *t*-test: $p > .05$).
(C) The socket-type defect achieved significantly higher bone gain than the horizontal and vertical complex type (Student's *t*-test: $p < .01$).

resorption with minor infection ($n = 5$, 10%), and temporary neurological disturbances ($n = 4$, 8%). In terms of the postsurgical course of each bone defect type, mesh exposures were found in 11 cases with the HV-type defect, six cases with the H-type defect, and one case with the S-type defect. Figure 4 shows the typical mesh exposure situation with HV-type bone defect. There were no statistically significant differences between the bone defect types (chi-square test: $p > .05$). However, all patients with the total or partial bone resorption displayed the HV-type defect; there were statistically significant differences in this case (chi-square test: $p < .05$). Figure 5 shows the relationship between the postsurgical complications and the bone defect type. Temporary neurological disturbances were found in four cases; they were all transient, with three of the four patients recovering within 2 weeks and the remaining patient recovering within 10 weeks.

Although several complications occurred after prosthesis placement, most of these problems did not influence the implant treatment results. Implant treatments were possible at 47 sites (94%), and 87 implants were installed. Table 3 shows the follow up period after implant insertion and implant failure. One implant failed because of the infection, and the cumulative implant survival rate was 92.8% by Kaplan–Meier estimate up to 96 months after implant surgery. The mean follow-up period was 47.5 months. Thread exposure occurred after superstructure installation in three cases,

TABLE 2 The Postsurgical Complications after Reconstruction and Prosthesis Placement

	Case/s	%
Complications after reconstruction		
Mesh exposure	18	36
Bone resorption		
Total bone resorption and early removal of titanium mesh due to infection	4	8
Partial bone resorption	5	10
Temporary neurological disturbance within 12 weeks	4	8
Complications after prosthesis placement		
Implant failure	1	2
Implant thread exposure	3	6
Implant removal due to psychiatric reason	1	2

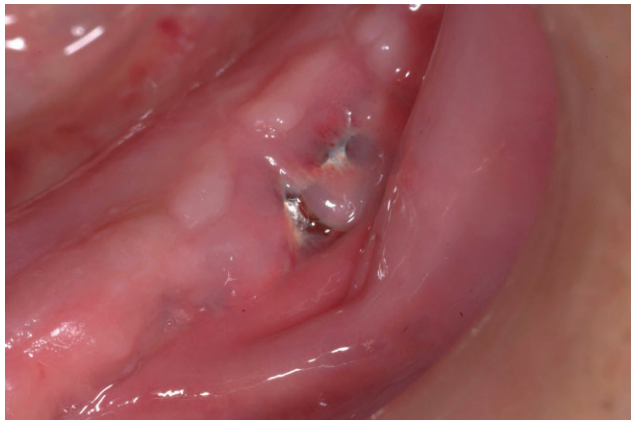

Figure 4 Mesh exposure 6 weeks after operation with titanium mesh and bone graft with HV-type bone defect. Clinically, there is no sign of inflammation.

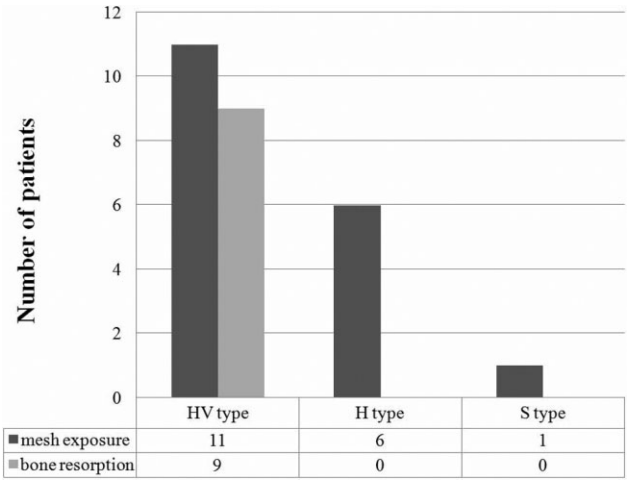

Figure 5 Graph showing the relationship between the bone defect type and the postsurgical complications. The horizontal–vertical complex defect (HV type) had significantly higher complications than the horizontal (H)-type and socket (S)-type defects.

two of which were treated with full-thickness palatal flap transplants. The superstructure was removed from one patient because of a psychiatric reason.

DISCUSSION

In this study, the augmented bone with titanium mesh and particulate autogenous bone graft was evaluated by CT. For successful long-term implant stability, the host bone status is an important factor.[15] Titanium is a metal with excellent biocompatibility and has been used in various surgical applications.[16,17] Bone augmentation with titanium mesh is a useful technique; the most likely hypothesis is its protective effect on augmented bone during healing.[18] In the present study, the augmented bone defects were stable and successful implant treatments were achieved with adequate bone quality and quantity, which is in accordance with a previous similar controlled study on nonresorbable membranes.[19] However, the quantitative and qualitative resorption of grafted bone is uncertain. In our previous studies, the dental implants were applied to the patients after alveolar clefts reconstruction with secondary bone graft using PCBM. The results demonstrated that the interdental alveolar height did not change after implant placement in a long-term follow-up, suggesting that the implants placed in the grafted alveoli maintain the alveolar bone height in the region.[4] On the other hand, the onlay block of cortico-cancellous bone is often grafted for the reconstruction of alveolar ridge. Depending on the series of research, the cumulative survival of implant is 80–90% because of the bone resorption.[20] For that reason, particulated bone graft was performed in the present study.

In the titanium mesh technique, easy handling of the titanium mesh allows three-dimensional reconstruction of relatively large bony defects including significant vertical deficits and cases with severe membranous tension.[21,22] The outcome of the augmented bone is usually determined by postoperative radiographic evaluations; therefore, there are few reports of three-dimensional evaluations based on CT data. In particular, the width of horizontal bone augmentation is uncertain.

As per the results, complex bone defects have higher possibilities of surgical complications, which may be rooted in the soft tissue condition after surgery. H- and S-type bone defects have relatively more periosteal coverage than the HV-type defect. Moreover, in HV-type bone defects, the tension of the mucosal or periosteal membrane after suturing would be higher than in the

TABLE 3 The Follow-Up Period after Implant Installation and Failed Implant

Follow-Up Period after Implant Insertion	Number of Augemented Sites	Number of Installed Implants	Number of Failed Implants	Implant Survival Probability (±SE) (%)
0–12	13	30	0	100
12–24	0	0	0	100
24–36	2	2	0	100
36–48	9	19	0	100
48–60	14	29	0	100
60–72	4	4	1	92.8 ± 0.07
72–84	1	4	0	92.8 ± 0.07
84–96	1	1	0	92.8 ± 0.07
Total	44	89	1	

other types of defects. These conditions affect adequate blood supply for wound healing. Therefore, it would result in a good healing process in the case of H- and S-type defects.

A major complication of the titanium mesh technique is mesh exposure during healing period. Membrane exposure of nonresorbable membrane barriers would result in infection, which can jeopardize the results.[6] Conversely, titanium mesh exposure did not appear to affect the final outcome. In this study, resuturing of the exposed mucosal membrane was first performed. When severe infection was recognized on careful observation, the mesh was removed, occurring only in the case of the HV-type defects. However, after about 1 or 2 weeks' healing, mesh exposure did not directly result in significant bone resorption, and the mesh seemed to tolerate infection. Even if the mesh is removed because of infection, partial bone necrosis or resorption would occur, and total bone resorption has not been observed.[23–26] The reason for this difference is unclear. A possible explanation is that titanium meshes allow blood supply exchange from the periosteum to the grafted bone, enabling nutrition of the grafted bone.[18,27,28] Titanium meshes have been shown to be rigid enough to prevent soft tissue collapse, thus maintaining space for the grafted bone and for formation of granulation tissue without a mucosal membrane. The tissue around titanium meshes is frequently observed after the healing period. In the early phase of wound healing, the newly formed tissue does not cover the sites under the membrane. If infection occurs in the grafted bone directly at this time, it would result in severe bone resorption. Conversely, after a few weeks of healing, the newly formed granulation tissue would cover the sites under the membrane; therefore, the augmented sites could resist infection without severe bone resorption. Moreover, in the GBR method, it is sometimes technically difficult to create a space below the membrane because of strong tension in large bone defects. Therefore, in this case, implant insertion is usually performed by using a staged approach with both titanium mesh and the GBR technique. Taken together, the titanium mesh technique has the advantage of allowing space creation for large bone defects.

CONCLUSION

The titanium mesh technique allows adequate three-dimensional augmentation with particulate bone grafts via a staged approach. There are several postsurgical complications, which depend upon the bone defect type. Horizontal and vertical complex bone defects have the highest number of complications. However, overall, bone augmentation with titanium mesh and autogenous particulate bone graft is a successful technique.

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