Evaluation of Sinus Floor Augmentation with Simultaneous Implant Placement Using Platelet-Rich Fibrin as Sole Grafting Material

Nobutaka Tajima, DDS, PhD[1]/Seigo Ohba, DDS, PhD[2]/
Takashi Sawase, DDS, PhD[3]/Izumi Asahina, DDS, PhD[4]

Purpose: *The objective of this study was to evaluate sinus floor augmentation with simultaneous implant placement using platelet-rich fibrin (PRF) as the only grafting material.* ***Materials and Methods:*** *This study included patients who underwent sinus floor augmentation with simultaneous implant placement using PRF as the sole filling material between July 2009 and January 2011 at the Department of Oral and Maxillofacial Surgery, Nagasaki University Hospital. For each patient, presurgical and postsurgical (6 months after the surgery) radiography and computed tomographic scanning were performed to assess bone formation at the implant sites. The density (in Hounsfield units [HU]) of the newly formed bone and the bone height from the sinus floor to the alveolar crest where implants were inserted were measured using implant planning software (Simplant, Materialise Dental).* ***Results:*** *Nine sinus floor augmentations were performed, and 17 implants were placed in six patients. The mean residual bone height between the sinus floor and alveolar crest was 4.28 ± 1.00 mm (range, 1.9 to 6.1 mm) prior to surgery and 11.8 ± 1.67 mm (range, 9.1 to 14.1 mm) after surgery. The alveolar bone ridge was wide enough for implant placement in all cases. The mean density of the newly gained bone around the implants was 323 ± 156.2 HU (range, 185 to 713 HU). All implants were clinically stable at the time of abutment insertion, 6 months after sinus augmentation.* ***Conclusion:*** *Sinus elevation with simultaneous implant placement using PRF as the only filling material may promote natural bone regeneration.* Int J Oral Maxillofac Implants 2013;28:77–83. doi: 10.11607/jomi.2613

Key words: *bone regeneration, dental implants, Hounsfield index, maxillary sinus, platelet-rich fibrin, resonance frequency analysis, sinus grafting*

In the posterior maxilla, the vertical height of bone available for implant placement is often limited. Sinus augmentation is a predictable method to expand bone volume in the maxilla in such cases. Sinus augmentation with autogenous bone grafts by the lateral window technique was reported by Boyne and James in the 1980s.[1]

[1]Assistant Professor, Department of Regenerative Oral Surgery, Unit of Translational Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan.
[2]Lecturer, Department of Regenerative Oral Surgery, Unit of Translational Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan.
[3]Professor, Department of Applied Prosthodontics, Unit of Translational Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan.
[4]Professor, Department of Regenerative Oral Surgery, Unit of Translational Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan.

Correspondence to: Dr Nobutaka Tajima, Nagasaki University Hospital, 1-7-1 Sakamoto, Nagasaki 852-8588, Japan. Fax: +81-95-819-7705. Email: n-tajima@nagasaki-u.ac.jp

Although sinus elevation with autogenous bone grafts is considered to be the gold standard, many researchers have attempted to modify this procedure because of the morbidity associated with bone harvesting. Various bone substitutes, such as xenogeneic, allogeneic, and some artificial materials, have been developed to reduce the risks associated with autogenous bone grafting.[2,3] However, the use of xenogeneic and allogeneic materials involves a risk of transmitting disease, and artificial bone substitutes have been found to be insufficient for osteogenic regeneration.[4]

Lundgren et al reported on a new method of sinus floor augmentation with whole blood as the sole filling material.[5] The authors suggested that the use of bone substitutes during sinus floor augmentation is not absolutely necessary because the natural blood clot inside the subsinus space is capable of promoting bone healing.[6,7] In this method, sinus elevation is performed by a lateral window technique with simultaneous implant placement, and then the space between the sinus membrane and maxillary bone is filled by whole blood, based on the concept of guided bone regeneration. The implants serve as "tent pegs" that maintain the sinus

Fig 1 *PRF preparation.*

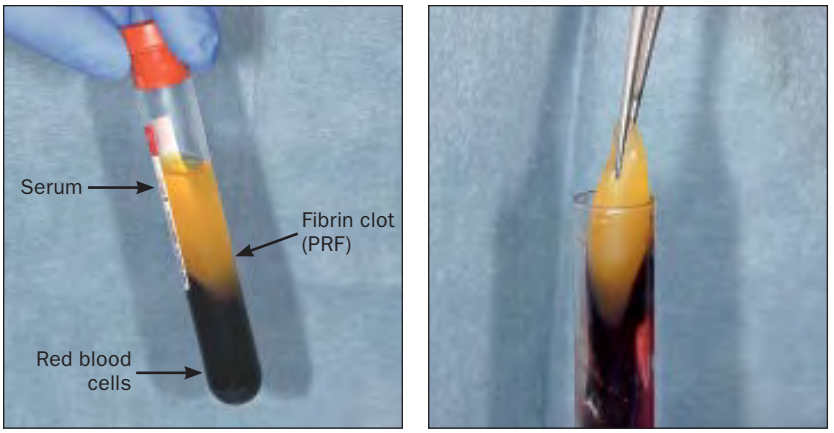

Fig 1a *(Left)* After centrifugation, the coagulation cascade leads to formation of a natural fibrin clot above the red blood cell layer (middle of the tube).

Fig 1b *(Right)* The fibrin clot can be removed from the tube, separated from the red cell base, and used as a grafting material.

membrane in an elevated position, and the blood clot filling the dead space serves as a scaffold for bone formation. This leads to natural bone regeneration around implants. However, it is often difficult to fill the sinus cavity with a stabilized blood clot. The use of blood preparations such as platelet concentrate or fibrin glue might be an interesting option to improve this approach.

Platelet-rich fibrin (PRF) is a simple, natural, and inexpensive blood product that is prepared by centrifugation of whole blood drawn into a tube without anticoagulant.[8–14] The coagulation cascade starts during centrifugation, and blood is divided into three parts in the tube: serum as a supernatant in the upper layer, the red blood cell layer at the bottom, and the PRF clot between them (Fig 1). PRF is an autologous fibrin matrix that is rich in platelets, leukocytes, and growth factors. Fibrin and fibrin clots, which are thought to be beneficial for bone regeneration, play an important role in wound healing. By protecting the denuded wound tissues and providing a scaffold for cell migration during the tissue repair process, they function as a temporary shield. Furthermore, fibrin also serves as a reservoir for cytokines and growth factors.[15] PRF has moderate strength, is easy to handle, and promotes healing of the sinus membrane and bone. PRF has many beneficial characteristics that make it suitable for application as a filling material for sinus floor augmentation. The purpose of this study was to validate the outcome of sinus floor augmentation with simultaneous implant placement using PRF clots as the sole filling material.

MATERIALS AND METHODS

Patients and Study Design

Patients who underwent sinus floor augmentation with simultaneous implant placement using PRF as the sole filling material between July 2009 and January 2011 at the Department of Oral and Maxillofacial Surgery, Nagasaki University Hospital, were included in the study. The patients were informed about the aim and design of the study, and written consent was obtained. This study was approved by the Internal Review Board at Nagasaki University Graduate School of Biomedical Sciences (approval no. 1071). Patients with immunologic diseases, uncontrolled diabetes mellitus, or other contraindicating systemic conditions were excluded from participation.

Presurgical evaluations of all patients included panoramic radiography and computed tomography (CT) scans. The residual bone height between the sinus floor and the alveolar crest where implants were to be inserted was determined using the CT scans. Implants with a slightly tapered body, grooves, and an oxidized surface (NobelSpeedy Groovy with TiUnite Surface, Nobel Biocare), which were designed to promote high primary stability in soft bone, were placed.

PRF Preparation

PRF was prepared as described elsewhere.[8,9,14] During surgery, 20 to 40 mL of whole blood was drawn into 9-mL sterile glass tubes without anticoagulant and then immediately centrifuged in a special machine (Medifuge MF200, Silfradent) using a program with the following parameters: 30 seconds of acceleration, 2 minutes at 2,700 rpm, 4 minutes at 2,400 rpm, 4 minutes at 2,700 rpm, 3 minutes at 3,000 rpm, and 36 seconds to decelerate and stop. The coagulation cascade led to the formation of a natural fibrin clot above the red blood cell layer, in the middle of the tube. Each clot was removed from the tube and separated from the red blood cell base with scissors; it was then used as a filling material for sinus floor augmentation (Fig 1).

Surgical Procedure

Surgery was performed under general anesthesia or local anesthesia with intravenous sedation. Access to

Fig 2 *Intraoral photographs of patient no. 3 during surgery.*

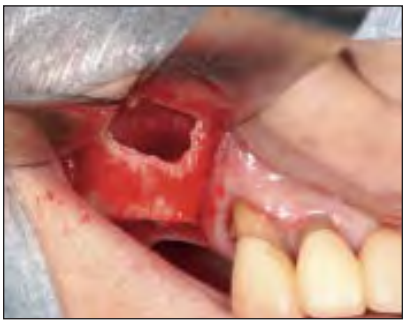

Fig 2a The sinus lateral bone window osteotomy has been performed and the sinus membrane has been elevated carefully without perforation.

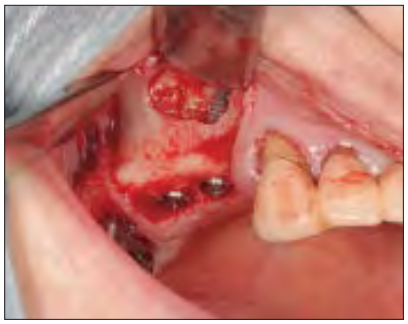

Fig 2b PRF clots are placed under the elevated membrane, and the implants are then placed.

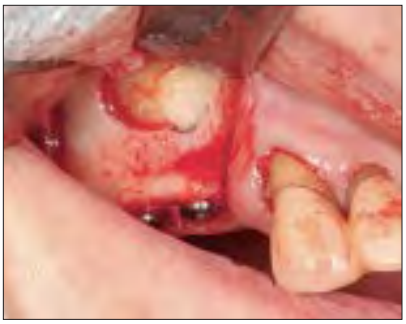

Fig 2c The PRF clot is placed on the window side of the implants. The subsinus cavity is filled with PRF clots.

the buccal maxillary wall was achieved by a mucosal crestal incision, anterior and posterior releasing vestibular incisions, and elevation of a full-thickness flap. A diamond round point in an ultrasonic lancet (Piezosurgery, Mectron) was used under constant saline irrigation to create a bone window in a medial position to preserve the buccal bone around the implant. Thereafter, the sinus membrane was carefully elevated without perforation. The bone window, which was left attached to the membrane, served as a new sinus floor. The membrane was peeled off extensively up to the nasal side of the sinus floor to expose the widest possible bone surface. Two or three PRF clots were placed under the elevated membrane, creating a space between the membrane and alveolar bone. The implant sites were then prepared by careful drilling, and implants were inserted. Implants were held by the residual alveolar bone and they served as "tent pegs," maintaining the membrane in an elevated position (Fig 2). The flaps were replaced and sutured with nylon thread. For postoperative management, medications were prescribed, including benzethonium chloride rinses twice a day for 14 days, 250 mg amoxicillin three times daily for 5 days, and 120 mg loxoprofen as needed for pain. The sutures were removed 7 days after the surgery.

Radiographic Evaluation

Panoramic radiographs and CT scans were obtained for each patient about 6 months after surgery to evaluate the bone formation around the implants. Planning software (Simplant, Materialise), was used to determine the density (in Hounsfield units [HU]) of the newly formed bone around the implant, and the volume of bone from the alveolar crest to the sinus floor at the implant sites was measured. Three-dimensional new bone volume was then calculated by stacking all the areas of new bone seen on the two-dimensional cross sections.

Resonance Frequency Analysis

Resonance frequency, represented by a quantitative unit called the implant stability quotient (ISQ) that ranges from 1 to 100, was measured using the Osstell Mentor device (Osstell) 6 months after surgery to validate the next step of the treatment. SmartPegs were mounted on the implants and tightened with a screw by hand. ISQ values in four directions were measured four times for each implant. The measurements were averaged for each implant.[16,17]

RESULTS

Nine sinus floor augmentations were performed and 17 implants were placed in six patients. The ages of the patients ranged from 53 to 82 years (mean age, 67.8 years). All the patients were women. No obvious sinus membrane perforations or complications during healing were seen in any of the patients after surgery. The presurgical residual bone height between the sinus floor and the alveolar crest where implants were to be inserted ranged from 1.9 to 6.1 mm (mean ± standard deviation [SD], 4.28 ± 1.00 mm). The alveolar bone ridge was wide enough to place implants in all sites, ranging from 5.3 to 9.8 mm (mean ± SD, 7.46 ± 1.15 mm). The baseline data of patients are shown in Table 1.

Implants of three different lengths were used: 10.0 mm (n = 1), 11.5 mm (n = 5), and 13.0 mm (n = 11). Although the insertion torque values were as low as 20 to 30 Ncm, no implants showed mobility.

Panoramic radiographs taken immediately after the surgery showed that the implants were inserted into the sinus cavity with no dense tissue around them, because PRF is radiolucent. However, 6 months after surgery, the sinus cavities around the implants were filled with a dense bonelike tissue (Fig 3). CT scans obtained 6 months after surgery showed significantly increased bone volume around implants; the mean bone height

Table 1 Baseline Characteristics of Subjects and Outcomes

Patient	Age (y)	Implant site*	Ridge width (mm)	Pre-BH (mm)	Post-BH (mm)	NBV (mL)	Implant diameter (mm)
1	82	16	7.5	4.9	11.2	0.45	4
		17	8.8	4.8	10.8		4
2	65	15	6.6	2.8	13.7	1.41	4
		16	7.4	3.1	14.1		4
3	64	15	5.4	3.5	12.4	0.64	4
		16	7.0	3.8	12.2		4
		25	5.3	4.3	14.1	0.92	4
		26	7.4	4.6	13.8		4
4	75	15	7.8	5.1	13.4	0.77	4
		16	9.8	4.6	12.4		4
		25	8.0	4.4	9.2	0.64	4
		26	8.6	4.8	10.7		4
5	53	16	7.2	4.6	10.0	0.39	4
		17	6.5	6.1	10.9		4
		26	7.8	4.3	12.0	0.56	4
		27	8.6	5.1	9.1		4
6	68	25	7.2	1.9	10.2	0.52	4
Mean			7.46	4.28	11.78	0.70	
SD			1.15	1.00	1.67	0.31	

*FDI tooth-numbering system used.
Pre-BH = presurgical bone height; post-BH = postsurgical hone height; NBV = new bone volume; ISQ = implant stability quotient; IT = insertion torque; NED = not enough data.

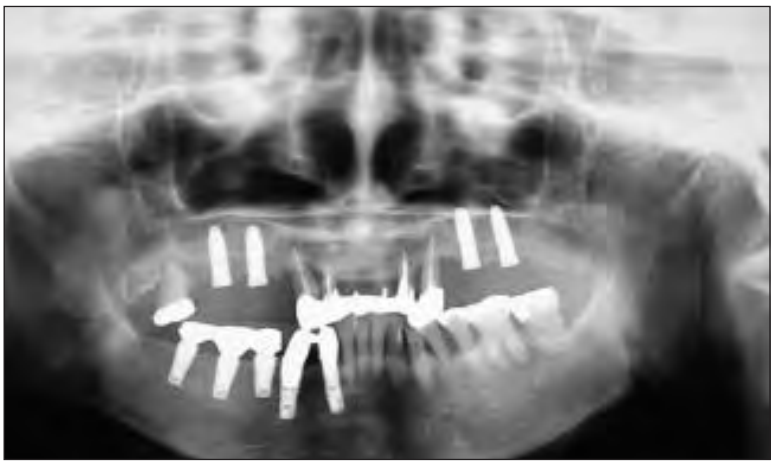

Fig 3a Panoramic radiograph taken just after surgery shows implants in the sinus cavity without dense tissue around them.

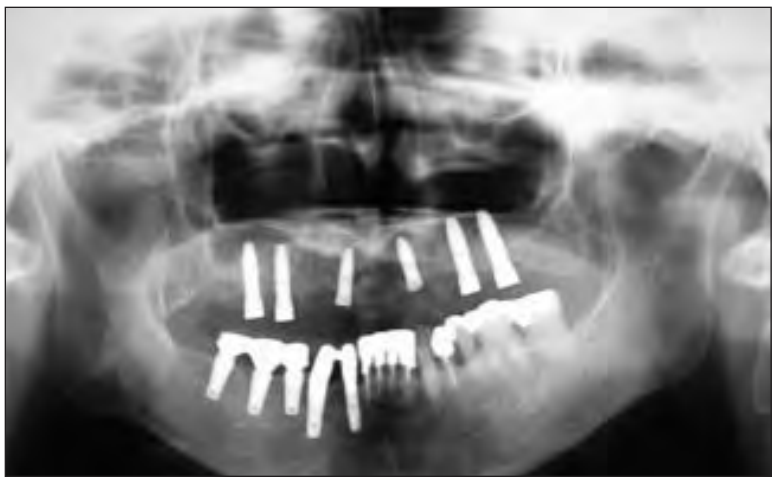

Fig 3b Six months after surgery, the sinus cavity around the implants is filled with dense bonelike tissue, and the border of the sinus floor has become obscured.

Implant length (mm)	HU	IT (Ncm)	ISQ
13	185	20	NED
13	192	20	NED
11.5	215	25	NED
13	242	25	NED
13	285	25	75
13	273	20	67
13	198	30	73
13	204	20	65
13	340	20	70
13	205	30	70
13	423	30	58
13	221	20	69
11.5	515	20	61
11.5	407	30	57
11.5	713	20	NED
11.5	589	20	NED
10	292	25	NED
12.38	323.47	23.53	66.50
0.93	156.23	4.24	6.15

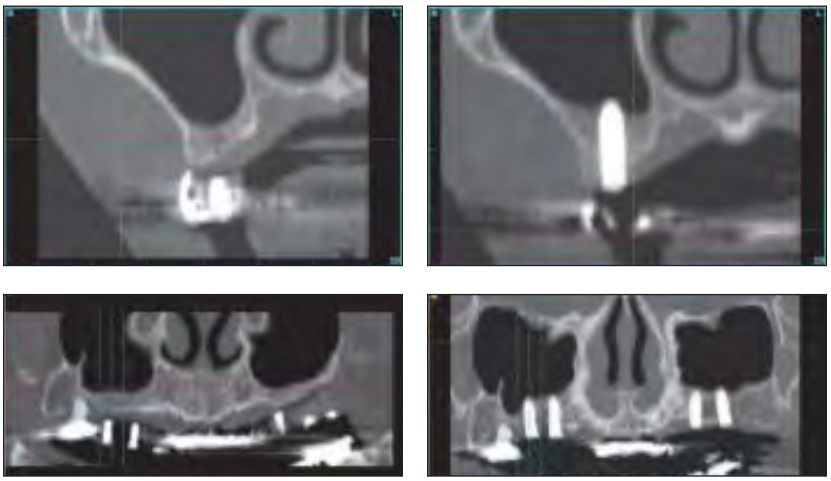

Fig 4 Presurgical and postsurgical CT scans from patient no. 3. (*Above*) The residual bone height of the treated site has increased from 3.8 to 12.2 mm. (*Below*) The sinus cavity around the implants is filled with newly formed bone.

between the sinus floor and the alveolar crest where implants were inserted was 11.8 ± 1.67 mm (range, 9.1 to 14.1 mm), an average gain of 7.5 mm from the original sinus floor. The mean density of the newly gained bonelike tissue around implants was 323 ± 156.2 HU (range, 185 to 713 HU) (Fig 4), and the average new bone volume was 0.70 ± 0.31 mL (Table 1). Although limited numbers of implants were analyzed, the mean ISQ was 66.5 ± 6.15 (range, 57 to 75 ISQ) 6 months after sinus elevation, at the time of stage-two surgery. This confirmed the stability of the implants, and all implants remained clinically stable during abutment tightening.

DISCUSSION

Recently, bone substitutes such as xenografts or artificial bone have been employed more often for sinus floor augmentation instead of autogenous bone grafts, mainly because of the morbidity associated with bone harvesting at intraoral and extraoral sites.[18–20] Many studies have reported favorable results when xenogeneic or artificial bone graft materials were used for sinus floor augmentation.[1–3,21–23] However, higher treatment costs and potential disease transmission remain matters of concern with xenografts. Most notably, the infectious particles of bovine spongiform

encephalopathy in cattle can cause Creutzfeldt-Jakob disease in humans.[4] Therefore, in terms of costs and the risk of infection, sinus floor augmentation without a bone grafting material might be a desirable approach.

In the present study, CT scans obtained 6 months after surgery revealed sufficient newly formed bone in all treated sites. Clinical examination also showed that all implants were stable at the 6-month follow-up appointments. The bone height between the sinus floor and the alveolar crest that received the implants ranged from 9.1 to 14.1 mm (mean ± SD, 11.8 ± 1.67 mm), which corresponded to the actual length of the inserted implants. Because the implants served as "tent poles" to maintain the height of the bone healing space, the final vertical bone volume was dependent on the implant length.

Bone density can be evaluated using Hounsfield units, which are directly related to tissue attenuation coefficients. A relative scale has been established using this parameter, and the range of values reported for different types of bone includes very dense cortical bone (> 600 HU), dense cortical/spongy bone (400 to 600 HU), and cortical/spongy bone of low density (< 200 HU).[24,25] In the present study, the density of the new bonelike tissue around implants ranged from 185 to 713 HU (mean ± SD, 323 ± 156.2 HU), which is comparable to that of the bone normally present in the posterior maxilla. Thus, the present study showed that sinus floor augmentation using PRF as the sole filling material was successful. This result is in agreement with other reports.[26,27]

The use of PRF instead of mere whole blood in sinus floor augmentation with simultaneous implant placement seems to be more beneficial and provide better results. However, the authors' interpretation is based only on observations of a cohort of relevant cases, and it is difficult to compare the effect of PRF with that of whole blood because the present study was performed without a control group. There are a number of reports about sinus elevation using only whole blood.[5–7,28–34] Although Thor et al achieved a good result (implant survival rate of 97.7%[32]), some reports in which no filling materials were used for sinus floor augmentation with simultaneous implant placement showed limited bone gain, and the apical ends of the implants were suspected to be enmeshed in sinus connective tissue.[34,35] Another report that used whole blood as the sole filling material resulted in less bone formation compared to the present study.[5]

A drawback of PRF is that it requires clinical setup, but its preparation is very simple. The clinician needs only to withdraw venous blood and centrifuge it with a specialized machine. An advantage of PRF versus whole blood is that there might be less likelihood of perforating the sinus membrane during drilling because PRF has some inherent stiffness to help keep the sinus membrane elevated.

PRF is regarded as a promising biomaterial that contains a strong fibrin matrix and ensures the slow release of growth factors, such as transforming growth factor, vascular endothelial growth factor, and platelet-derived growth factor.[14] These major growth factors released from platelets stimulate cell proliferation and migration to promote wound healing.[10,11,35] Many studies have used PRF for various procedures, such as periodontal surgery, implant placement, and sinus floor augmentation.[12–14,26,27,36] PRF is known to accelerate soft and hard tissue healing, which might explain the favorable results observed in the present study.

It should also be noted that the surgical technique can affect outcomes. With the present surgical technique, it is important to prevent invasion of soft tissue into the space surrounded by bone. Although in the present study no membranous materials or barriers were placed at the bone window to prevent soft tissue invasion, the bone window was kept as small as possible and placed in a medial position to preserve the buccal bone to support the implants. In addition, simultaneous implantation with sinus floor augmentation is thought to be essential for the success of this technique. PRF is known as an autogenous fibrin matrix that constricts after surgery and is gradually absorbed. Therefore, sinus floor augmentation with PRF as the sole filling material without simultaneous implant placement may not be adequate to maintain a wide space under the elevated sinus membrane during new bone formation and maturation, which will result in insufficient bone volume.[31,32] Therefore, the use of this method is contraindicated in sites in which the implants lack primary stability because of insufficient residual bone around the implants.

CONCLUSION

Platelet-rich fibrin is an autologous and inexpensive material, which can be considered as an optimized blood clot. Sinus floor augmentation with simultaneous implant placement using platelet-rich fibrin as the sole filling material is a secure and reliable option that promotes natural bone regeneration.

ACKNOWLEDGMENTS

The authors reported no conflicts of interest related to this study.

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