Long-Term Outcomes of Implants Placed in Autogenous Onlay Bone Grafts Harvested from Mandibular Ramus and Risk Analysis

Kang-Mi Pang, DDS, PhD[1]/Yoojin Shin, DDS, MSD[2]/Joo-Young Park, DDS, PhD[2]/Bongju Kim, PhD[3]/
Soung Min Kim, DDS, PhD[2]/Jong-Ho Lee, DDS, PhD[2,3]

Purpose: This study evaluated the long-term survival and success rates of dental implants placed with autogenous onlay block bone grafts harvested from the mandibular ramus. ***Materials and Methods:*** Patients treated with onlay bone graft from the mandibular ramus due to a severe vertical alveolar defect from 2001 to 2017 were included in this study. The marginal bone loss, success, and survival time of the implants were recorded and analyzed with clinical factors, such as time from bone graft to implant placement, type of implant prosthesis connection, history of periodontitis, and insertion depth. ***Results:*** Seventy-five implants in 40 onlay bone-grafted areas of 38 patients were included, with a mean follow-up period of 102 months (range: 14 to 192 months). Two grafts were removed before implant placement. Of the 75 implants, 11 implants were lost. History of periodontitis and marginal bone loss at 6 months after implant placement were significantly associated with implant success. The receiver operating characteristic curve showed that a marginal bone loss of 0.75 mm after 6 months of implant placement was related to implant success, with a sensitivity of 72.2% and specificity of 89.6%. ***Conclusion:*** Implants placed with onlay bone graft from ramal bone had more frequent biologic complications, and failures may be predicted by measuring the amount of implant bone loss after 6 months of placement. *Int J Oral Maxillofac Implants 2021;36:745–754. doi: 10.11607/jomi.8602*

Keywords: dental implant, mandibular ramus, onlay bone graft, vertical bone deficit

Dental implants are a reliable and predictable restorative procedure. With the advancement of bone substitutes and barrier membranes, bone augmentation procedures are currently performed with minor invasive surgery.[1] However, vertical alveolar bone deficiency remains a main obstacle for implant placement, especially in cases in which the implant placement is adjacent to anatomical structures such as the inferior alveolar nerve. Diverse surgical techniques have been developed to resolve these problems, such as guided bone regeneration (GBR), autogenous onlay bone graft, and distraction osteogenesis.

Autogenous bone grafts have been the gold standard in bone grafts due to their osteogenic, osteoinductive, and osteoconductive properties.[2] The selection of donor sites largely depends on the amount of graft required. When large amounts are necessary, grafts are mainly harvested from the iliac crest or calvarium; in cases that only require small amounts, grafts from intraoral sites are often recommended, primarily from the symphyseal region or the ascending ramus. The advantages of grafts harvested from the mandible are the minimal morbidity and avoidance of distant donor sites.[3–5] Moreover, membranous bone, such as the mandible or calvarium, undergoes less resorption than endochondral bone, such as the iliac crest or tibia.[6,7] The mandibular ramus is frequently used over the symphysis due to the minimal concern for the alteration of facial contour and fewer postoperative complications, such as sensory disturbances of the lower lip.[2] Onlay bone graft is often selected when the height of the alveolar ridge is < 5 mm,[8] and clinical results are reported to be favorable, with implant survival rates ranging from 60% to 100%.[9] For example, Chiapasco et al reported favorable long-term results with severely resorbed ridges reconstructed with calvarial or mandibular block bone.[10,11]

[1]Department of Oral and Maxillofacial Surgery, Seoul National University Dental Hospital, Seoul, Republic of Korea.
[2]Department of Oral and Maxillofacial Surgery, School of Dentistry, Seoul National University, Seoul, Republic of Korea.
[3]Dental Life Science Research Institute and Innovation Research & Support Center for Dental Science, Seoul National University Dental Hospital, Seoul, Republic of Korea.

Correspondence to: Prof Jong-Ho Lee, Department of Oral and Maxillofacial Surgery, Dental Life Science Research Institute and Innovation Research & Support Center for Dental Science, Seoul National University Dental Hospital, 101 Daehakno, Jongno-gu, Seoul 03080, Republic of Korea. Fax: +82-2-766-4948.
Email: leejongh@ snu.ac.kr

Submitted May 12, 2020; accepted December 27, 2020.

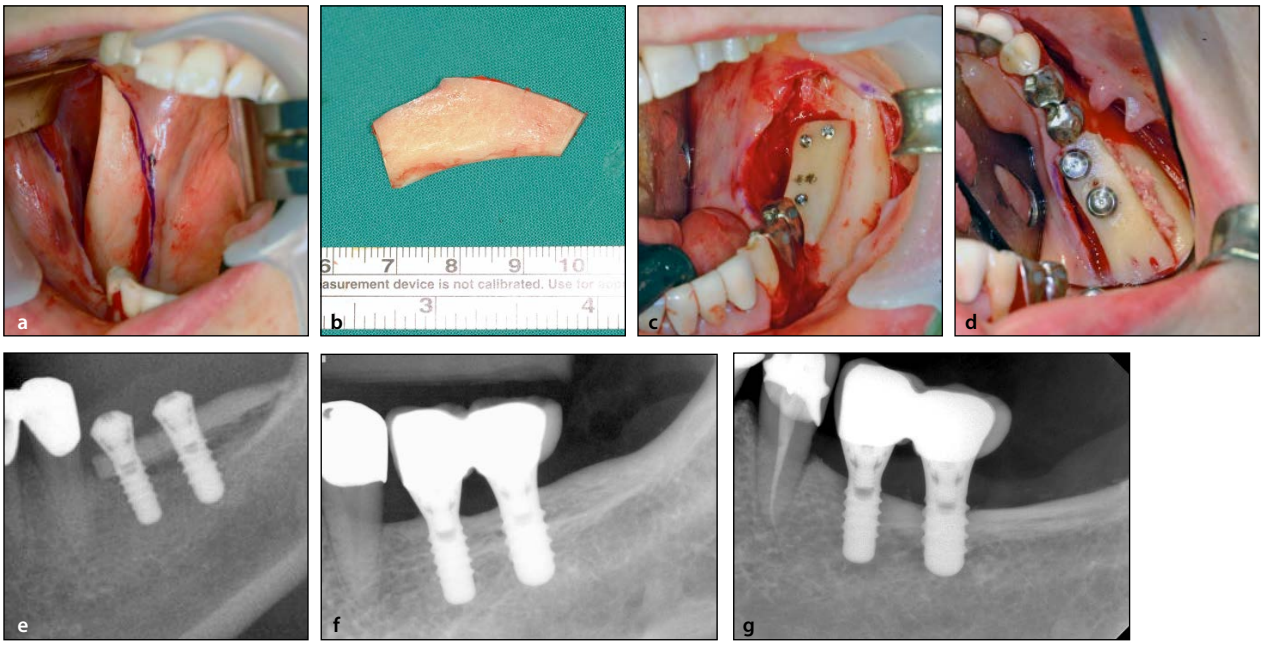

Fig 1 Onlay bone graft harvested from the contralateral mandibular ramus. *(a)* Donor site (right mandibular ramus) before block harvesting. *(b)* Harvested bone block from the mandibular ramus. *(c)* Vertical reconstruction of the alveolar ridge with bone blocks. Site of implant insertion was marked with pencil. *(d)* After placement of implant, fixing screws were removed when implant was placed simultaneously. Clinical view of grafted bone and placed implant. *(e)* Panoramic radiograph taken immediately after surgery. *(f)* Periapical view after 2 years. *(g)* Periapical view at 11 years postoperatively.

However, except for the report by Chiapasco et al,[10,11] studies evaluating implants with onlay block bone graft over a period at least 10 years have been insufficient.

The purpose of the present retrospective study was to evaluate the long-term cumulative survival and success rates of implants placed in alveolar ridges reconstructed with onlay bone grafts harvested from the mandibular ramus. The factors related to implant success were also analyzed.

MATERIALS AND METHODS

This retrospective analysis of clinical records included consecutive patients who were treated by onlay bone graft harvested from the mandibular ramus from 2001 to 2017 at the Department of Oral and Maxillofacial Surgery, Seoul National University Dental Hospital. Patients with a severe vertical alveolar defect of a partially or completely edentulous area that impeded the placement of a short implant (7 mm) were included. All patients were in good health, without any disease that would contraindicate surgery. Patients with a follow-up period < 6 months were excluded except for the early removal of grafted bone. All surgeries were performed by two surgeons (S.K., J.L.). The study protocol and access to the patient records were approved by the Institutional Review Board of Seoul National University Dental Hospital, Seoul, Korea (ERI19044).

Surgical Procedure

All operations were carried out under local anesthesia or intravenous sedation. Ramal bone was harvested as described by Misch.[12] The planned implant site was exposed for the measurement of the required amount of bone. The osteotomy of the donor site was performed using a small fissure bur and a microdisc bur in a straight handpiece. A thin chisel was used to gently tap along the entire length of the external oblique osteotomy and then levered to pry the buccal segment free. The harvested cortical bone block was trimmed, adjusted, and fixed to the recipient site with titanium screws. Next, a mixture of the remaining autogenous bone chips and xenogeneic bone was grafted around the blocks. Periosteal releasing incisions were used to achieve tension-free closure of flaps on top of the grafts. The implants were inserted simultaneously or several months after the bone graft (Fig 1). There were no specific criteria to determine whether the implant was placed simultaneously or several months after the graft. Implant prostheses were fabricated after 4 months in the mandible and 6 months in the maxilla.

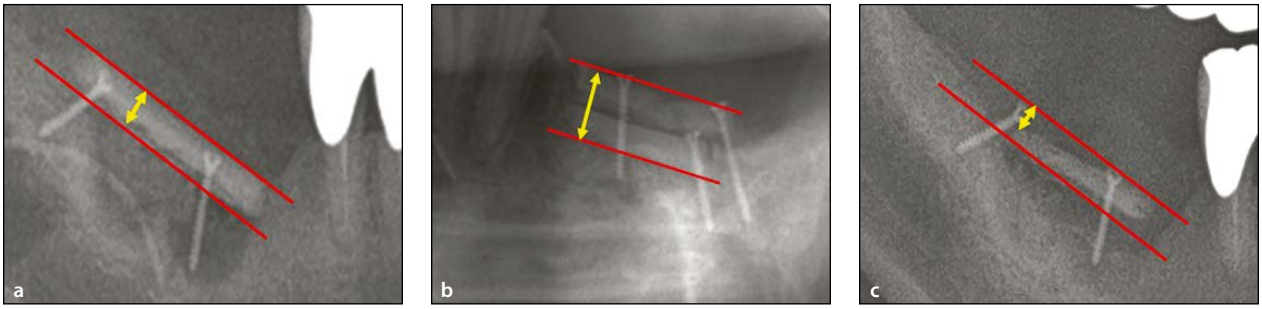

Fig 2 Measurement of the amount of bone gain and resorption amount. *(a)* Vertical alveolar bone gain was measured using immediate postoperative radiograph. Distance between the upper margin and lower margin of the onlay bone was calculated at the mesial, middle, and distal areas, and the average value was obtained. *(b)* Two bone blocks were augmented. *(c)* At 6 months after bone grafting, the distance between the top of the screw head (or implant) and the most upper level of bone-to-screw (or implant) contact was calculated in the mesial, middle, and distal areas of the grafted bone, and an average value was obtained; the average values were compared with those in postoperative radiographs.

Evaluation

Postoperative complications were evaluated during the healing phase. For the radiographic analysis, panoramic radiographs were taken before and after bone augmentation (before and after implant placement if the implant was not placed simultaneously), 6 months after implant placement, and every year after implant insertion. If alveolar bone loss was > 3 mm or the tooth was extracted because of a periodontal problem in the nongrafted area during the follow-up period, these patients were considered to have periodontitis.

Vertical Bone Gain

Vertical alveolar bone gain was measured using an immediate postoperative radiograph. The distance between the upper margin and lower margin of the onlay bone was calculated at the mesial, middle, and distal areas, and an average value was obtained (Figs 2a and 2b).

Amount of Bone Resorption

At 6 months after bone grafting, the distance between the top of the screw head (or implant) and the most upper level of bone-to-screw (or implant) contact was calculated in the mesial, middle, and distal areas of the grafted bone, and an average value was obtained; the average values were compared with those in postoperative radiographs (Fig 2c). If the implant was placed simultaneously, the distance from the implant shoulder and the first bone-to-implant contact (DIB) mesially and distally to the implant were measured to calculate the amount of grafted bone resorption at 6 months after bone grafting.

After implant placement and during the follow-up period, DIB was measured, and marginal bone loss (MBL) of the implant was calculated.

Before calculating the augmented bone height and MBL, the enlargement ratio of the image was determined using the implant length (measured length of bone loss × actual length of the implant/measured length of the implant). In the case of bone grafting and separate implant placement, the enlargement ratio was calculated with the length of the fixing screw. The digital radiographic images were acquired using a charge-coupled device detector (Suni Medical Imaging) in combination with SDR software (Mjrad Corporation). All measurements were taken by one examiner (K.P.).

Evaluation of Implant Success and Survival Rate

Success rates were based on the criteria of Albrektsson and colleagues for success, allowing 1.5 mm of MBL in the first year of function and 0.2 mm annually thereafter. Implant survival was defined as the implant still functioning at the end of the follow-up period without peri-implant infection with suppuration; without persistent pain, dysesthesia, mobility, or continuous peri-implant radiolucency; and with bone resorption > 1.5 mm in the first year and > 0.2 mm in subsequent years.[13]

Statistical Analysis

The statistical tests were based on an implant as the unit. The Kaplan-Meier method was used to draw the implant survival and success curve and to calculate the cumulative survival and success rate. Survival times were recorded from implant placement to either the date of implant removal or failure (uncensored observations) or the date of last follow-up (censored observations). Hazard ratios from univariate Cox regression analysis were used to determine which variables were associated with implant success. Next, using four variables with low *P* values, multivariate Cox proportional hazards regression analysis with backward conditional was performed to evaluate independent prognostic factors associated with implant success. The receiver-operating characteristic (ROC) curve was used to

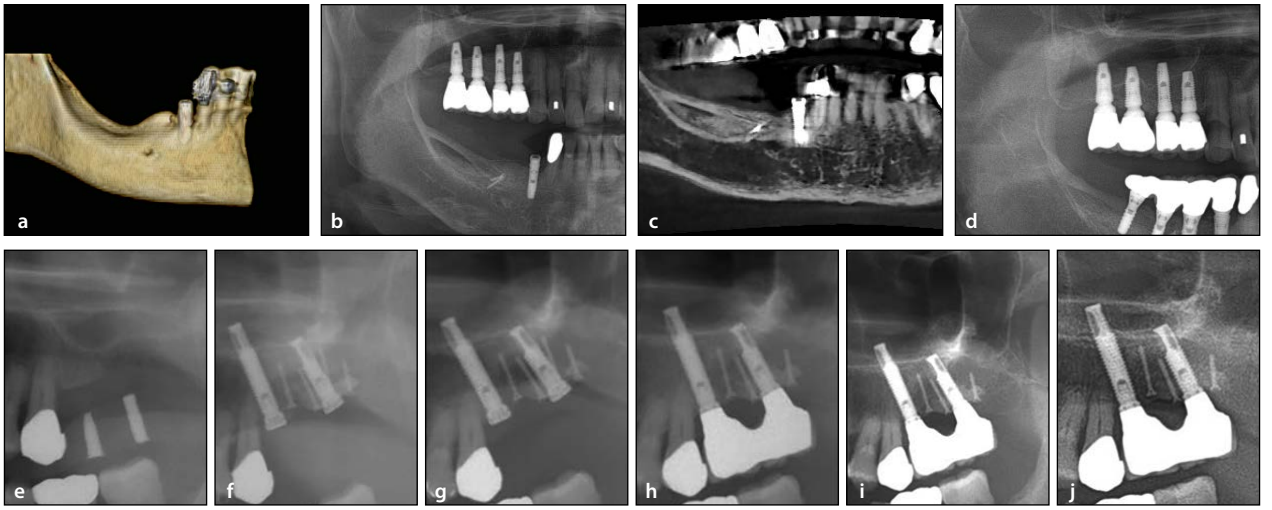

Fig 3 Radiographs of the two patients with a large amount of vertical bone gain. *(a)* Preoperative 3D reconstruction of the CT. *(b)* Panoramic radiograph after onlay graft with right mandibular ramus. *(c)* CT taken 6 months after implant placement shows integration of the graft bone and new bone formation of the gap between the alveolar bone and grafted bone. *(d)* Panoramic radiograph taken 2 years after the placement of the implant. *(e)* Panoramic radiograph of another patient with vertical defect in left maxillary posterior area. *(f)* Panoramic radiograph after two-block onlay graft. Implants were placed simultaneously. Panoramic radiograph taken *(g)* 6 months, *(h)* 1.5 years, *(i)* 3 years, and *(j)* 5 years after the placement of the implant.

Table 1 Demographic Characteristics of Patients and Implants

Grafted site–based	
No. of patients (M:F)	38 (20:18)
No. of grafted sites	40
Age (years, mean ± SD)	52.22 ± 12.69
Grafted area (no.)	
Maxilla anterior	2
Maxilla posterior	9
Mandible anterior	1
Mandible posterior	28
Implant-based	
No. of implants (M:F)	75 (41:34)
Age (y, mean ± SD)	52.29 ± 13.91
Area of implant placement (no.)	
Maxilla anterior	7
Maxilla posterior (right:left)	17 (10:7)
Mandible anterior	7
Mandible posterior (right:left)	44 (16:28)
Length of implants (no.)	
< 10 mm	13
10–12 mm	24
> 12 mm	38
Type of implant (external:internal, no.)	34:41
Follow-up period (mo, mean ± SD)	102 ± 55
Range (m)	14–192
Overall periodontitis	43

determine the sensitivity and specificity of the statistically significant variable. To evaluate the effect of variables on implant MBL, the Mann-Whitney *U* test was used. The significance level was set as $P < .05$. All data were analyzed using the Statistical Package for the Social Sciences (SPSS software Version 23.0, SPSS).

RESULTS

Thirty-eight patients (mean age: 52.2 years, M:F = 20:18) with 40 grafted sites were included in this study. The graft size at bone procurement (n = 40) was 2.63 ± 1.17 cm (from 1 cm to 7 cm) in length and 1.22 ± 0.67 cm (from 0.7 cm to 4 cm) in vertical height (Fig 1b). In two patients, two bone blocks were augmented (Fig 2b, Figs 3e to 3f). Recipient site incision dehiscence occurred in two patients; one of them was augmented with two bone blocks, and the grafted bone was removed between 3 and 6 months postoperatively. A total of 75 implants were placed in 36 grafted sites with a mean follow-up period of 102 ± 55 months (range: 14 to 180 months). In 17 patients, 38 implants were placed simultaneously, while 37 implants in 19 patients were placed after a healing period ranging from 4 to 10 months after the grafting procedure. All implants were osseointegrated. Implant length, type, anatomical position, and existence of periodontitis are listed in Table 1.

Radiographic Evaluation

The amount of vertical bone gain was 5.74 ± 2.11 mm (from 3.3 to 13 mm, Fig 3). The amount of grafted bone resorption at 6 months after bone grafting was

Table 2 Changes of Marginal Bone Loss from Placement of Implant Over Time and Comparison of Variables on Bone Loss

	6 mo	1 y	3 y	5 y	7 y	10 y	13 y	15 y
Total	0.56 ± 0.72 (64)	1.03 ± 1.15 (55)	1.23 ± 1.45 (39)	1.86 ± 2.14 (41)	1.89 ± 2.10 (33)	1.54 ± 1.59 (23)	2.24 ± 1.68 (12)	2.75 ± 3.06 (11)
Succeeded implant	0.30 ± 0.32 (46)	0.57 ± 0.52 (39)	0.88 ± 0.89 (28)	1.03 ± 1.06 (31)	1.18 ± 1.14 (26)	1.38 ± 1.43 (22)	1.93 ± 1.68 (10)	1.67 ± 1.82 (9)
Failed implant	1.24 ± 0.99 (18)	2.14 ± 1.49 (16)	2.13 ± 2.14 (11)	4.46 ± 2.58 (10)	4.53 ± 2.78 (7)	5 (1)	3.78 ± 0.37 (2)	7.63 ± 3.01 (2)
P value[a]	.001	< .001	.102	.001	.002	.087	.273	.036
Implant with simultaneous bone graft	0.56 ± 0.75 (32)	1.15 ± 1.05 (25)	1.33 ± 1.45 (25)	2.01 ± 2.09 (28)	2.24 ± 2.18 (23)	2.16 ± 1.70 (14)	2.24 ± 1.68 (12)	2.75 ± 3.06 (11)
Implant 4–9 mo after bone graft	0.57 ± 0.71 (32)	0.93 ± 1.24 (30)	1.06 ± 1.48 (14)	1.55 ± 2.29 (13)	1.07 ± 1.72 (10)	0.57 ± 0.73 (9)		
P value[a]	.856	.054	.176	.143	.074	.007		
Internal	0.57 ± 0.76 (31)	1.17 ± 1.05 (23)	1.34 ± 1.49 (23)	2.06 ± 2.15 (26)	2.20 ± 2.24 (22)	2.03 ± 1.79 (13)	2.22 ± 1.86 (10)	2.75 ± 3.06 (11)
External	0.55 ± 0.70 (33)	0.93 ± 1.23 (32)	1.07 ± 1.41 (16)	1.52 ± 2.14 (15)	1.26 ± 1.69 (11)	0.90 ± 1.7 (10)	2.35 ± 0.04 (2)	
P value[a]	.861	.052	.217	.127	.191	.042	1	

Data are expressed in mean ± SD (number of implants).
[a]The *P* values were calculated using the Mann-Whitney test.

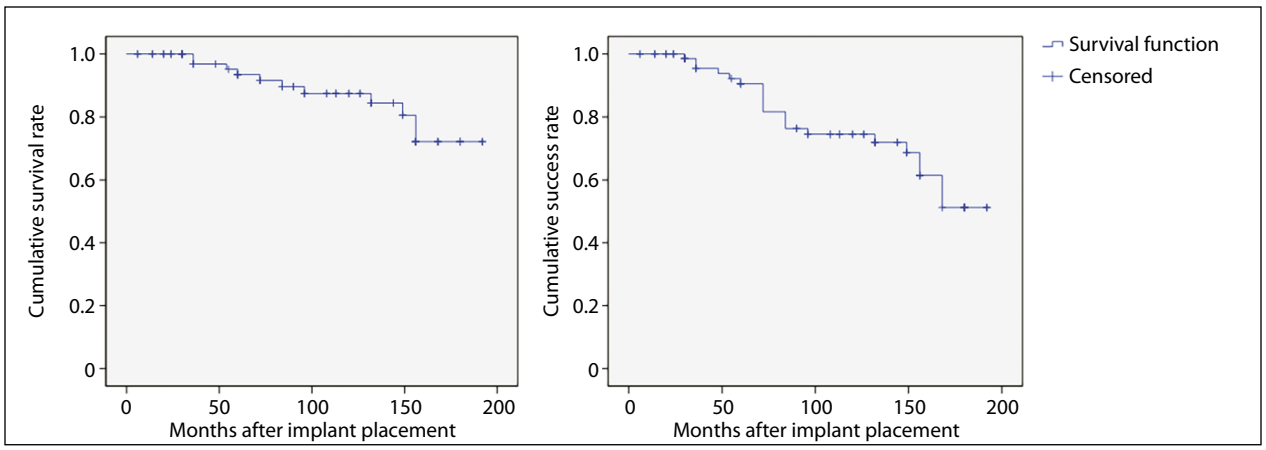

Fig 4 Kaplan-Meier plot of implant survival (time to implant loss) and implant success.

0.51 ± 0.51 mm (from 0 to 2.25 mm). Implant MBL at 6 months and at 1, 5, and 10 years after implant placement was 0.56 ± 0.72, 1.03 ± 1.15, 1.86 ± 2.13, and 1.53 ± 1.59 mm, respectively. When MBL was calculated in the successful implant, 0.30 ± 0.32, 0.57 ± 0.52, 1.03 ± 1.06, and 1.38 ± 1.43 mm of implant marginal bone were lost at 6 months and at 1, 5, and 10 years after implant placement, while failed implants showed 1.24 ± 0.99, 2.14 ± 1.49, and 4.46 ± 2.58 mm at 6 months and at 1 and 5 years, with statistical significance at 6 months and at 1, 5, 7, and 15 years (*P* = .001, < .001, .001, .002, and .036, respectively; Table 2).

Changes of MBL according to the time of implant placement and bone grafting showed statistical differences only at 10 years after implant placement (*P* = .007), while mean values were higher in implants placed simultaneously with bone grafts for all time intervals except 6 months. Similarly, the type of abutment connection also showed statistical differences only at 10 years after implant placement (*P* = .042).

Success and Survival Rates of Implants

Eleven implants among 75 implants were lost. Two implants were removed at 3 years after implant placement, 1 at 4 years, 1 at 5 years, 1 at 6 years, 1 at 7 years, 1 at 8 years, 1 at 11 years, 1 at 12.5 years, and 2 at 13 years. Failures were a result of peri-implantitis accompanied by grafted bone resorption. The implant survival rates at 5, 10, and 15 years were 94.8%, 90.9%, and 85.7%, respectively. The cumulative 5-year, 10-year, and 15-year survival rates were 93.5%, 87.4%, and 72.1%, respectively.

As for implant success, 21 out of 75 implants did not meet the implant success criteria, including 11 lost

Table 3 Variables Associated with Implant Success

	Univariate analysis[a]				Multivariate analysis[c]			
	Hazard ratio	95% CI		*P* value	Hazard ratio	95% CI		*P* value
		Lower	Upper			Lower	Upper	
Age	0.974	0.945	1.005	.098				
Sex								
Male	2.159	0.853	5.461	.104				
Female	0[b]							
Position	0.885	0.639	1.225	.462				
Months from bone graft to implant placement	1.092	0.960	1.242	.182				
Length of implant	0.876	0.756	1.015	.078				
Amount of bone gain	0.874	0.689	1.109	.267				
Type of implant								
External	1.198	0.474	3.029	.704				
Internal	0[b]							
Insertion depth	1.066	0.670	1.697	.787				
Presence of periodontitis								
Yes	2.536	0.916	7.025	.073	5.357	1.294	22.168	.021
No	0[b]							
Marginal bone loss at 6 months after implantation	3.591	2.252	5.728	< .001	4.861	2.638	8.959	< .001

[a]Hazard ratios from univariate Cox regression analysis were used to determine which variables were associated with implant survival.
[b]Parameters set to zero as a reference.
[c]Using four variables with low *P* value, multivariate Cox proportional hazards regression analysis with backward conditional was performed to evaluate independent prognostic factors associated with implant survival.

implants. The 5-year, 10-year, and 15-year cumulative implant success rates were 90.5%, 74.5%, and 51.2%. The implant survival and success curves are shown in Fig 4.

Risk Factor Analysis

Hazard ratios from the univariate Cox regression analysis are listed in Table 3. The amount of MBL 6 months after implant placement correlated with the implant success ($P < .001$). Five variables with P values < .3 were analyzed with Cox multivariate regression analysis. Periodontitis and MBL at 6 months after implant placement were significantly associated with implant success (hazard ratio for the history of periodontitis vs no periodontitis, 5.357; 95% confidence interval [CI], 1.294 to 22.168; $P = .021$; hazard ratio according to MBL, 4.861; 95% CI, 2.638 to 8.959; $P < .001$; Fig 5).

The ROC curve, using implant failure as an endpoint for MBL 6 months after implant placement (MBL6), is presented in Table 4 and Fig 6. The area under the curve (AUC) of MBL6 was 0.761 ($P = .001$). The relationship between the threshold of MBL and implant success is shown in Table 4 and Fig 6, and the optimal threshold (0.75 mm) is highlighted. Among 21 failed or lost implants, 13 implants showed MBL6 > 0.75 mm, and these implants failed within 8 years after implant placement. The number of failed or lost implants within 8 years after placement was 15, and only two implants that were lost at 5 years and 7 years had MBL6 < 0.75 mm.

Donor Site Complications

Donor site infection occurred in three cases and was controlled with surgical drainage and medication. The incidence of inferior alveolar nerve or buccal nerve sensory discomfort of the donor site was 12 cases out of 40 cases immediately after the operation. After 6 months, no patients reported symptoms of paresthesia.

DISCUSSION

The purpose of this retrospective study was to analyze the long-term results (maximum 16 years) of the onlay bone graft using bone blocks harvested from the mandibular ramus where the height of the alveolar bone was insufficient. Few studies have analyzed the long-term survival rates of implants placed in vertically augmented bone. In a study on autogenous onlay bone graft, Chiapasco et al reported that the survival

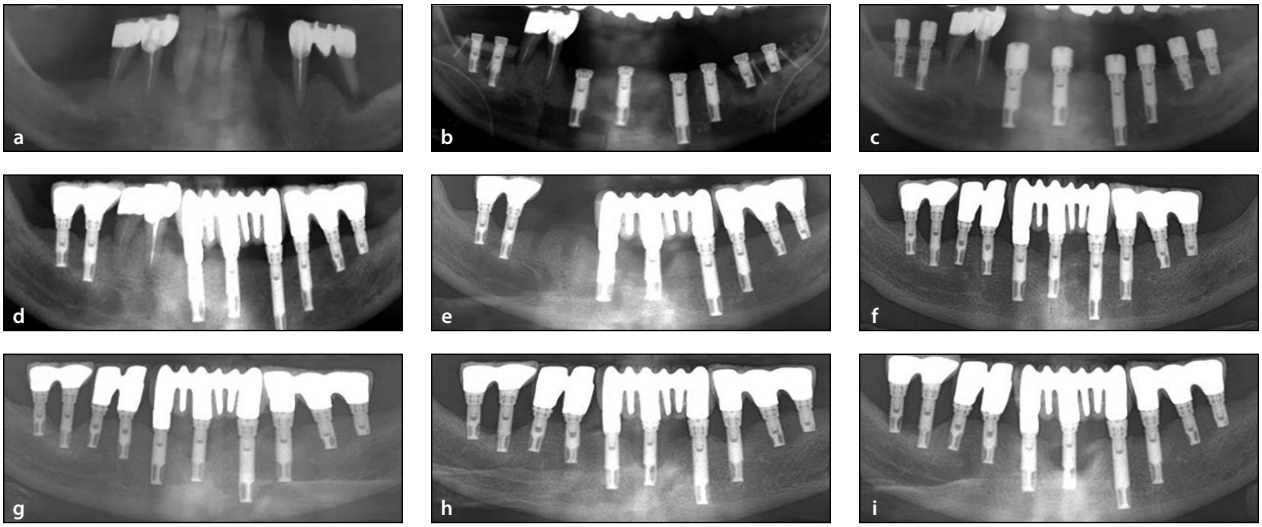

Fig 5 Panoramic radiograph of the patient with bilateral onlay graft in posterior mandible. *(a)* Preoperative panoramic radiograph showing partial edentulism in bilateral posterior mandible with a vertical defect. *(b)* Immediate postoperative radiograph. Implants were placed simultaneously with onlay bone grafts. *(c)* Panoramic radiograph taken after stage-two surgery of the submerged implants (6 months after implant placement). *(d)* Panoramic radiograph taken 1 year after the placement of the implant. Right mandibular first molar showed increased marginal bone loss. Panoramic radiograph taken *(e)* 3 years, *(f)* 5 years, *(g)* 12 years, *(h)* 14 years, and *(i)* 16 years after the placement of the implant. Right mandibular first and second molars were considered implant failures at 14 years, while left mandibular implants were successful for 16 years. Failed implants (right first molar) showed peri-implant bone loss, while adjacent implants (right second molar) in the same grafted bone were intact for 9 years. This patient had periodontitis of adjacent teeth (right first and second premolars), which were extracted 3 years after implant placement.

Table 4 Relationship Between Amount of Marginal Bone Loss and Implant Success

	Implant survival	
MBL (mm)	**Sensitivity**	**Specificity**
0.495	0.722	0.783
0.530	0.722	0.804
0.565	0.722	0.826
0.645	0.722	0.848
0.730	0.722	0.870
0.750[a]	0.722[a]	0.891[a]
0.775	0.667	0.891
0.815	0.667	0.935
0.885	0.667	0.957

[a]Signifies the optimal threshold.
MBL = mm of marginal bone loss at 6 months after implant placement.

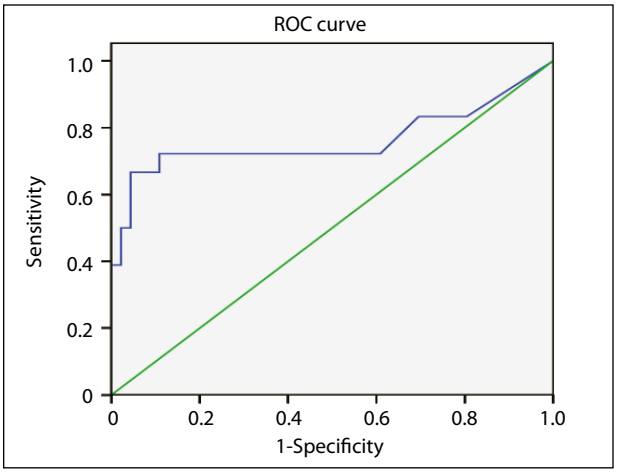

Fig 6 The relationship between the amount of marginal bone loss and implant success. Diagonal segments are produced by ties.

rate of implants at the end of the observation period from 3 to 19 years with a mean follow-up period of 8.1 years was 98.5% with calvarial bone graft.[11] In cases with autogenous mandibular bone block graft, the cumulative implant survival and success rates were 98.11% and 85.16%, respectively, with a mean follow-up period of 10 years, ranging from 3 to 16 years.[11] In other studies, the 10-year implant survival rate using iliac bone was 95% in the posterior maxilla,[14] and the 5-year implant success rate was 91.5% with iliac bone graft in the posterior maxilla,[15] while a 100% implant survival rate was reported using ramal bone graft with a 33-month follow-up period.[16] In a systematic review by Aghaloo and Moy, the implant survival rate was 90.4% for autogenous onlay/veneer bone graft with a follow-up ranging from 5 to 74 months.[17] In GBR, the implant survival rate was 93.2% after 12.5 years[18] and 94.8% after a 10-year follow-up.[19] The cumulative survival and success rate of the present study at 5 years was 93.5% and 87.4% and at 10 years was 90.5% and 74.5%, which

was somewhat lower than rates reported in previous studies, despite the use of rather loose success criteria of implants by Albrektsson, which was usually used in external-hex and machined-surface implants. Some of the patients in the present study were lost during follow-up for several years, then returned complaining of discomfort of the placed implant. In these patients, regular oral hygiene care was not carried out, and this may be related to the relatively lower implant survival and success rates. Risk factor analysis also showed similar tendencies. Patients with periodontitis showed a hazard ratio of 5.357 compared with those without periodontitis with a *P* value of .021 in multivariate Cox analysis, although there was no significance in univariate analysis. Considering the successful 10-year results of Roccuzzo et al, with an implant survival rate of 94.8%, patients were regularly followed up and placed on an individually tailored maintenance care program for supporting periodontal therapy.[19] Simonis et al also found that patients with a history of periodontal disease have lower implant survival rates and were more susceptible to biologic complications such as peri-implantitis and mucositis.[20] The ITI consensus 2018 reported that the prevalence of peri-implantitis in grafted sites is more variable and less predictable than those in pristine bone.[21] The failed implants of the present study showed peri-implant bone loss, while the same grafted bone of adjacent implants was intact. Therefore, it seemed that the success of the implant placed on vertically augmented bone was related to the implant hygiene and progress of periodontitis.

In the present study, risk factor analysis showed that whether the implant was placed simultaneously or secondarily was not related to implant success. MBL showed no statistical differences at any time period except 10 years after implant placement. These results were in contrast to other studies, which showed marked differences in implant success, survival rate, and MBL. For iliac bone graft, in the study by Triplett and Schow, 83.6% of the implants placed simultaneously with bone grafting were successful, while 90.4% of implants placed secondarily after a consolidation period were successful.[22] The percentage of bone loss of vertical alveolar height between iliac grafting and 4 to 6 months before implant placement was 33%.[23] Lundgren et al found that the delayed-approach implant showed a higher degree of bone-to-implant contact and more new bone formation in iliac bone graft cases.[24] Similarly, in calvarial and mandibular bone graft, most studies inserted the implant after approximately 4 to 6 months post-grafting, although average bone resorption was much lower than iliac graft.[13,25,26] These studies suggested waiting from 4 to 9 months due to the slow revascularization and remodeling processes of mandibular bone blocks.[27,28] However, Iizuka et al inserted 31 implants secondarily and 11 implants primarily with calvarial bone graft and obtained a survival rate of 100% in both groups.[25] The prospective study by Jung et al on implants placed simultaneously with GBR after 12.5 years also showed an overall survival rate of 93%, which was higher than other long-term studies.[18] Therefore, earlier studies that directly compared the time of implant placement used iliac bone, which had a relatively higher resorption rate, and studies of membranous bone did not show clinically different results.[25,29] The present study also showed no differences in implant success rates. However, the amount of bone resorption is open to interpretation, and the result of simultaneous placement of implants with membranous bone graft needs to be further evaluated in clinical trials.

Due to the relatively higher implant failure rate, the present study was able to analyze the risk factors involved with implant failure. A previous report showed that late implant failures on onlay bone graft were usually a result of peri-implantitits.[30] The present study showed the same tendencies, and most of the failures occurred between 3 and 8 years. To identify the predictive factors influencing implant success, the present study analyzed the amount of bone loss at 6 months of implant placement. The amount of MBL at 6 months of implant placement showed a 4.861 hazard ratio in multivariate Cox analysis. The ROC curve showed that the 0.75-mm level had high sensitivity and specificity. No reports have shown bone loss at 6 months and compared them with the implant success. Implant bone loss was shown to be higher in the first year and then to decrease.[31] In a study on ramal onlay bone graft by Kim et al, MBL was 0.3 ± 0.3 mm after 4 months of implant placement with a 94.1% implant survival rate.[32] Chiapasco et al found that the mean peri-implant bone resorption was 0.23 to 0.28 mm (range: 0 to 1 mm) after 33 months (range: 12 to 68 months),[9] and Roccuzzo et al reported that the 10-year mean bone loss was 0.58 ± 0.57 mm with a cumulative 10-year survival rate of 94.48%.[19] These results suggest that successful implants showed MBL < 0.75 mm in early days. Most of the present cases with MBL > 0.75 mm at 6 months failed between 3 and 8 years. If marginal bone is resorbed to some extent, it is hard to maintain oral hygiene, which will cause peri-implantitis that leads to progressive alveolar bone loss and implant failure. This also suggests that peri-implantitis could be sustained for 3 to 8 years. Because of the relatively small number of cases, it is difficult to confirm implant MBL > 0.75 mm at 6 months as a risk factor; therefore, further study is important.

Some studies reported that internal connections had lower MBL compared with external connections, although it had no influence on the implant's

complication and survival rates.[33] However, the present study showed no statistical differences between internal and external connections in implant survival and success and most MBL except at 10 years of implant placement. These unexpected results concerning prosthetic connection were similar to the study by Chiapasco et al, which compared the platform-switching concept (Straumann Bone Level) and transmucosal concept implants (Straumann Tissue Level); the authors reported a higher implant success rate and low MBL in the tissue-level implant.[16] The authors speculate that the clinical effect of connection between the implant and abutment may be different in reconstructed bone.

This study had one limitation: There were no data for the height of the keratinized gingival tissue. Keratinized gingival tissue was associated with the maintenance of good oral hygiene, especially in posterior implants.[34] Chiapasco et al reported that vestibuloplasty with free gingival grafts had a positive and statistically significant effect on implant failure, peri-implantitis, and bone loss in calvarial bone graft, while there was no statistical significance in mandibular bone graft.[10,11] Although Jung et al reported that the height of keratinized mucosa was not correlated with alveolar bone loss,[18] soft tissue parameters such as keratinized gingival width, probing depth, and Plaque Index should be reviewed in future long-term studies. Furthermore, due to the retrospective nature of the study, patients were not followed up regularly. Therefore, it is hard to know when a critical event, such as initiation time of rapid MBL, occurred.

CONCLUSIONS

This retrospective study showed that implants placed with onlay bone graft harvested from the mandibular ramus had cumulative 5-year, 10-year, and 15-year survival rates of 93.5%, 87.4%, and 72.1%, respectively. The 5-year, 10-year, and 15-year cumulative implant success rates were 90.5%, 74.5%, and 51.2%, respectively. Implants with periodontitis of other teeth and marginal bone loss at 6 months after implant placement > 0.75 mm had a higher risk of implant failure.

ACKNOWLEDGMENTS

This research was supported by a grant of the Korea Health Technology R&D Project through the Korea Health Industry Development Institute (KHIDI), funded by the Ministry of Health & Welfare, Republic of Korea (grant number : HI20C2114). The authors reported no conflicts of interest related to this study.

REFERENCES

1. Salvi GE, Monje A, Tomasi C. Long-term biological complications of dental implants placed either in pristine or in augmented sites: A systematic review and meta-analysis. Clin Oral Implants Res 2018;29(suppl 16):294–310.
2. Sakkas A, Ioannis K, Winter K, Schramm A, Wilde F. Clinical results of autologous bone augmentation harvested from the mandibular ramus prior to implant placement. An analysis of 104 cases. GMS Interdiscip Plast Reconstr Surg DGPW 2016;5:Doc21.
3. Capelli M. Autogenous bone graft from the mandibular ramus: A technique for bone augmentation. Int J Periodontics Restorative Dent 2003;23:277–285.
4. Clavero J, Lundgren S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation: Comparison of donor site morbidity and complications. Clin Implant Dent Relat Res 2003;5:154–160.
5. Soehardi A, Meijer GJ, Strooband VF, de Koning M, Stoelinga PJ. The potential of the horizontal ramus of the mandible as a donor site for block and particular grafts in pre-implant surgery. Int J Oral Maxillofac Surg 2009;38:1173–1178.
6. Cordaro L, Amadé DS, Cordaro M. Clinical results of alveolar ridge augmentation with mandibular block bone grafts in partially edentulous patients prior to implant placement. Clin Oral Implants Res 2002;13:103–111.
7. Phillips JH, Rahn BA. Fixation effects on membranous and endochondral onlay bone graft revascularization and bone deposition. Plast Reconstr Surg 1990;85:891–897.
8. Maestre-Ferrín L, Boronat-López A, Peñarrocha-Diago M, Peñarrocha-Diago M. Augmentation procedures for deficient edentulous ridges, using onlay autologous grafts: An update. Med Oral Patol Oral Cir Bucal 2009;14:e402–e407.
9. Chiapasco M, Casentini P, Zaniboni M, Corsi E. Evaluation of peri-implant bone resorption around Straumann Bone Level implants placed in areas reconstructed with autogenous vertical onlay bone grafts. Clin Oral Implants Res 2012;23:1012–1021.
10. Chiapasco M, Tommasato G, Palombo D, Del Fabbro M. A retrospective 10-year mean follow-up of implants placed in ridges grafted using autogenous mandibular blocks covered with bovine bone mineral and collagen membrane. Clin Oral Implants Res 2020;31:328–340.
11. Chiapasco M, Tommasato G, Palombo D, Scarnò D, Zaniboni M, Del Fabbro M. Dental implants placed in severely atrophic jaws reconstructed with autogenous calvarium, bovine bone mineral, and collagen membranes: A 3- to 19-year retrospective follow-up study. Clin Oral Implants Res 2018;29:725–740.
12. Misch CM. The harvest of ramus bone in conjunction with third molar removal for onlay grafting before placement of dental implants. J Oral Maxillofac Surg 1999;57:1376–1379.
13. Chiapasco M, Zaniboni M, Rimondini L. Autogenous onlay bone grafts vs. alveolar distraction osteogenesis for the correction of vertically deficient edentulous ridges: A 2–4-year prospective study on humans. Clin Oral Implants Res 2007;18:432–440.
14. Schmitt C, Karasholi T, Lutz R, Wiltfang J, Neukam FW, Schlegel KA. Long-term changes in graft height after maxillary sinus augmentation, onlay bone grafting, and combination of both techniques: A long-term retrospective cohort study. Clin Oral Implants Res 2014;25:e38–e46.
15. Wiltfang J, Schultze-Mosgau S, Nkenke E, Thorwarth M, Neukam FW, Schlegel KA. Onlay augmentation versus sinuslift procedure in the treatment of the severely resorbed maxilla: A 5-year comparative longitudinal study. Int J Oral Maxillofac Surg 2005;34:885–889.
16. Chiapasco M, Casentini P, Zaniboni M. Implants in reconstructed bone: A comparative study on the outcome of Straumann tissue level and bone level implants placed in vertically deficient alveolar ridges treated by means of autogenous onlay bone grafts. Clin Implant Dent Relat Res 2014;16:32–50.
17. Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are the most successful in furnishing bony support for implant placement? Int J Oral Maxillofac Implants 2007;22(suppl):49–70.
18. Jung RE, Fenner N, Hämmerle CH, Zitzmann NU. Long-term outcome of implants placed with guided bone regeneration (GBR) using resorbable and non-resorbable membranes after 12–14 years. Clin Oral Implants Res 2013;24:1065–1073.

19. Roccuzzo M, Savoini M, Dalmasso P, Ramieri G. Long-term outcomes of implants placed after vertical alveolar ridge augmentation in partially edentulous patients: A 10-year prospective clinical study. Clin Oral Implants Res 2017;28:1204–1210.
20. Simonis P, Dufour T, Tenenbaum H. Long-term implant survival and success: A 10–16-year follow-up of non-submerged dental implants. Clin Oral Implants Res 2010;21:772–777.
21. Heitz-Mayfield LJ, Aaboe M, Araujo M, et al. Group 4 ITI Consensus Report: Risks and biologic complications associated with implant dentistry. Clin Oral Implants Res 2018;29(suppl 16):351–358.
22. Triplett RG, Schow SR. Autologous bone grafts and endosseous implants: Complementary techniques. J Oral Maxillofac Surg 1996;54:486–494.
23. Bell RB, Blakey GH, White RP, Hillebrand DG, Molina A. Staged reconstruction of the severely atrophic mandible with autogenous bone graft and endosteal implants. J Oral Maxillofac Surg 2002;60:1135–1141.
24. Lundgren S, Rasmusson L, Sjöström M, Sennerby L. Simultaneous or delayed placement of titanium implants in free autogenous iliac bone grafts. Histological analysis of the bone graft-titanium interface in 10 consecutive patients. Int J Oral Maxillofac Surg 1999;28:31–37.
25. Iizuka T, Smolka W, Hallermann W, Mericske-Stern R. Extensive augmentation of the alveolar ridge using autogenous calvarial split bone grafts for dental rehabilitation. Clin Oral Implants Res 2004;15:607–615.
26. von Arx T, Buser D. Horizontal ridge augmentation using autogenous block grafts and the guided bone regeneration technique with collagen membranes: A clinical study with 42 patients. Clin Oral Implants Res 2006;17:359–366.
27. Aalam AA, Nowzari H. Mandibular cortical bone grafts part 1: Anatomy, healing process, and influencing factors. Compend Contin Educ Dent 2007;28:206–212.
28. Acocella A, Bertolai R, Colafranceschi M, Sacco R. Clinical, histological and histomorphometric evaluation of the healing of mandibular ramus bone block grafts for alveolar ridge augmentation before implant placement. J Craniomaxillofac Surg 2010;38:222–230.
29. Corinaldesi G, Pieri F, Sapigni L, Marchetti C. Evaluation of survival and success rates of dental implants placed at the time of or after alveolar ridge augmentation with an autogenous mandibular bone graft and titanium mesh: A 3- to 8-year retrospective study. Int J Oral Maxillofac Implants 2009;24:1119–1128.
30. Sethi A, Kaus T, Cawood JI, Plaha H, Boscoe M, Sochor P. Onlay bone grafts from iliac crest: A retrospective analysis. Int J Oral Maxillofac Surg 2020;49:264–271.
31. Oh TJ, Yoon J, Misch CE, Wang HL. The causes of early implant bone loss: Myth or science? J Periodontol 2002;73:322–333.
32. Kim JW, Cho MH, Kim SJ, Kim MR. Alveolar distraction osteogenesis versus autogenous onlay bone graft for vertical augmentation of severely atrophied alveolar ridges after 12 years of long-term follow-up. Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:540–549.
33. Lemos CAA, Verri FR, Bonfante EA, Santiago Júnior JF, Pellizzer EP. Comparison of external and internal implant-abutment connections for implant supported prostheses. A systematic review and meta-analysis. J Dent 2018;70:14–22.
34. Kim CS, Duong HP, Park JC, Shin HS. Preservation of keratinized mucosa around implants using a prefabricated implant-retained stent: A case-control study. J Periodontal Implant Sci 2016;46:329–336.