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Factors Influencing the Success of Nonvascularized Iliac Bone Graft for Mandibular Reconstruction: A Retrospective Study of 26 Cases

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Abstract

Objective: This study aimed to identify the prognostic factors influencing the success of nonvascularized iliac bone grafts for mandibular reconstruction.

Methods: This was a retrospective cohort study conducted at a single center, involving 26 patients who underwent segmental mandibulectomy followed by nonvascularized iliac bone grafts between 2012 and 2022 at the Oral and Maxillofacial Surgery Unit, Buddhachinaraj Phitsanulok Hospital. Data were collected by reviewing electronic medical records and radiographic images. Patients who had received vascularized bone grafts or had a history of head and neck irradiation therapy were excluded from the study. The patients were classified into two groups: successful and failed. Success was defined as clinical and radiographic evidence of bone continuity, a graft resorption rate not exceeding 30% of the initial height, and no evidence of chronic infection for at least 6 months.

Results: Successful bone grafting was achieved in 19 patients (73.1%). Multivariable risk difference regression analysis identified that the factors influencing graft incorporation were jaw immobilization using reconstruction plates with maxillomandibular fixation for at least 21 days (RD 63.0; 95% CI 33.1, 93.0; $p<0.001$) and long segmental block graft design (51.3%; 95% CI 16.9, 85.7; $p<0.003$). A clinically significant factor, although statistically insignificant, was the duration of plate stabilization, which should ideally range from 172 to 232 days prior to plate removal. The sample size constituted a limitation of this study.

Conclusions: Nonvascularized bone grafting remains a viable option for reconstructing mandibular segmental defects. The factors influencing graft stability can help improve clinical outcomes.

Keywords: iliac crest bone graft, mandibular reconstruction, nonvascularized bone graft

Introduction

The mandible is involved in masticatory and swallowing functions, including airway maintenance and facial aesthetics. The presence of facial injuries, aggressive benign lesions, malignant neoplasms, or extensive osteomyelitis can result in loss of mandibular function and deformities.(1) Currently, autogenous vascularized and nonvascularized bone grafts are the standard treatment for mandibular reconstruction.(2-4)

The vascularized bone grafts (VBGs) commonly used are the fibula free flap (FFF) and deep circumflex iliac artery free flap (DCIA), which are considered the ideal choice for mandibular reconstruction because these grafts provide a robust blood supply and adequate tissue support.(4) This reconstructive technique is used for large bone defects or non unions. The immediate blood supply to the graft, established through anastomosis, helps maintain the viability of the graft, preventing necrosis and enhancing the chances of successful integration into the recipient bone. The living bone cells within the graft continue their natural processes, such as osteogenesis and remodeling, leading to more effective and faster healing. However, limitations of the VBG option remain due to greater donor site morbidity, longer operating times, and the need for a hospital with specialized resources and surgeons with specific knowledge and expertise.(5,6)

Nonvascularized bone grafts (NVBGs), a type of bone grafting procedure used to promote bone healing and regeneration, involve the transplantation of bone tissue without its original blood supply. Graft healing relies on the recipient site to revascularize the transplanted bone, which is slower and more limited compared to VBGs. Generally, NVBGs are used for small to moderate bone defects, non-unions, and in dental procedures such as alveolar ridge augmentation and socket preservation.(6) The iliac crest bones are often preferred, and rib grafts are recommended for lateral defect reconstruction.(1,7) The advantages of NVBGs include easier harvesting and transplantation, less donor site morbidity, and shorter surgical periods and hospital stays compared to VBGs.(5,8) This operation can be performed in general and regional hospitals with sufficient resources.

Although NVBGs are often considered in patients with no history of radiation exposure to the head and neck area, they are typically used when the amount of recipient soft tissue is adequate, and the defect length is no more than 6 cm. However, it remains controversial whether NVBGs should be used for mandibular defects greater than 6 cm in patients with sufficient soft tissue beds. Other factors that promote bone healing, such as graft stability and the type of rigid reconstruction plate used to aid graft incorporation, also play a role.(1,9-12) The treatment approach for each patient is determined through a collaborative decision-making process involving both the surgeon and the patient, with careful consideration of donor site morbidity and the anticipated success rate of bone grafting.

The aim of this study is to evaluate the prognostic factors influencing the success of nonvascularized iliac crest bone grafts for mandibular reconstruction over a minimum of six months. Understanding these factors may help in developing clinical practice guidelines and improving patient outcomes.

Materials and Methods

This was a prognostic factor study using a retrospective observational cohort design that recruited 26 patients who had undergone segmental mandibulectomy for ameloblastoma of the mandible, followed by either immediate or delayed NVBGs. The surgeries were performed by a single surgeon at a single center in the Oral and Maxillofacial Surgery Unit Buddhachinaraj Phitsanulok Hospital, between 2012 and 2022. This study was submitted to and approved by the Buddhachinaraj Phitsanulok Hospital Institutional Review Board (COA No.153/2566, HREC No.172/2566).

Data were collected by reviewing electronic medical and surgical records, including radiographic data taken preoperatively, intraoperatively, and postoperatively. The inclusion criteria were patients diagnosed with benign mandibular neoplasms who had undergone NVBGs for segmental mandibular defects. Patients with a history of head and neck radiation therapy, those who had undergone VBGs for mandibular reconstruction, and those with incomplete data were excluded from the study.

To investigate the factors influencing the success of NVBGs in a cohort of 26 patients, it was determined that the mean duration of jaw immobilization in the success group was 34.3±14.4 days, while in the failure group it was 8.6±15.7 days, revealing a statistically significant difference. Consequently, the means were estimated using STATA 16.1 software (Stata Corp LLC, United States), employing a one-sided test with a significance level of 0.05 and a power of 0.90. The failure-to-success ratio was calculated to be 0.37 (7:19), indicating that the sample sizes for the success and failure groups should be at least 12 and 5, respectively.

The independent variable was NVBGs for segmental mandibular defects after mandibulectomy for benign tumors. All patients were diagnosed with intraosseous ameloblastoma and underwent preoperative oral prophylaxis for dental caries or periodontal disease. A two-layer watertight intraoral closure was performed after tumor resection. All NVBGs were harvested from the anterior iliac crest using a mono-corticocancellous block graft technique (Figure1). Preoperative antibiotic prophylaxis was administered intravenously and continued for 10-14 days postoperatively, either intravenously or orally. The autogenous block grafts were used to reconstruct mandibular defects in either immediate or delayed reconstruction. In cases where there is a risk of losing soft tissue bed coverage at the recipient site due to the expansion of a large benign tumor, particularly in regions involving the symphysis, delayed reconstruction is typically the preferred approach.[1,2] The grafts were stabilized with either a 2.7-mm non locking or a 2.4-mm locking reconstruction plate system (Synthes) due to the requirement for sufficient strength. Jaw immobilization with MMF was performed for graft stability during the immediate postoperative phase for 4–6 weeks, unless contraindicated (e.g., risk of airway compromised due to respiratory disease, seizure, or patient refusal). Radiographic examinations were performed within the first week postoperatively and at least every 4–6 months thereafter. Reconstruction plates were removed after 6–8 months to prevent stress shielding once graft stabilization was achieved (Figure 2).

The main outcome variable was the classification of patients into successful and failed graft incorporation groups. Successful bone graft incorporation was defined as clinical and radiographic evidence of bone continuity, with graft resorption not exceeding 30% of the initial height and no evidence of chronic infection for at least 6 months. The bone resorption rate was assessed by comparing the grafted bone height obtained from immediate postoperative panoramic radiographs with measurements taken from radiographs at the 6 month follow-up.

Covariates included preoperative demographics, perioperative and postoperative factors such as gender, age, smoking and alcohol consumption history, body weight, height, BMI, comorbidities, mandibular defect classification, symphysis involvement, bone graft length, timing of reconstruction, graft stabilization method, MMF time, plate stabilization time, long segmental block graft design union , graft infection, and total graft loss.

Mandibular defect locations were classified according to Brown *et al.*'s classification of mandibular defects based on the four corners of the mandible, as this classification closely matched our patient data.[13] The classifications are: Class I (angle) - lateral defect at the angle without involvement of the ipsilateral canine or condyle; Class Ic (angle and condyle) - lateral defect involving the condyle (disarticulation); Class II (angle and canine) - hemi-mandibulectomy defect involving the ipsilateral angle and canine but sparing the contralateral canine or condyle; Class IIc (angle, canine, and condyle) - hemi-mandibulectomy defect involving the ipsilateral condyle; Class III (both canines) - anterior mandibulectomy defect involving both canines but sparing both angles; Class IV (both canines and at least one angle) - extensive anterior mandibulectomy defect involving both canines and at least one angle; Class IVc (both canines and at least one condyle) - extensive anterior mandibulectomy defect involving both canines and at least one condyle (Figure 3). After harvesting the anterior iliac crest bone graft, it was determined that the size of the monocortico-cancellous bone graft was primarily 4–7 cm in length and 4–5 cm in width. Therefore, the bone shape must be adjusted before securing it with a reconstruction plate, ensuring that the bone height does not exceed 3 cm to prevent occlusal interference. Total bone graft length and the design of long segmental block grafts were assessed using panoramic radiographs and by measuring the retained reconstruction plate in each patient, regardless of whether a 2.7-mm non locking plate or a 2.4-mm locking plate was utilized. The distance between the plate holes of the 2.7-mm non locking and 2.4-mm locking reconstruction plates is 0.8 cm.

This research was analyzed using the STATA 16.1 software (Stata Corp LLC, United States) to compare data between the successful and failed groups. Categorical variables were analyzed using the exact probability test, while numerical variables were analyzed using the Student's t-test and the Wilcoxon rank-sum test to compare means and standard deviations (SD). Factors influencing graft incorporation success were analyzed using multivariable risk difference regression, with results presented as risk differences (RD %).

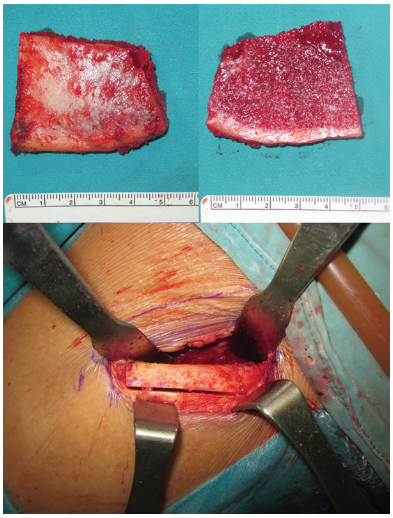

Figure 1: The mono-corticocancellous block graft technique was performed using bone harvested from the anterior iliac crest.

Results

A total of 26 patients with NVBGs were included in this study. We found that 19 patients achieved iliac crest bone graft incorporation following segmental mandibulectomy, representing a success rate of 73.1% (Table 1). When comparing the two groups (successful and failed), the majority of patients were male in both groups (57.9% vs. 71.4%). However, females had a higher proportion of success (42.1% vs. 28.6%, respectively). The patients in the success group were younger on average (36.4±12.3 years vs. 44.1±9.9 years, respectively). However, gender and age were not found to be significant variables in predicting graft failure (p=0.668 and p=0.146, respectively). The mean weight was statistically higher in the success group (74.3±13.6 kg vs. 59.3±6.2 kg; p=0.010), as was the mean height (164.9±5.9 cm vs. 157.3±6.9 cm; p=0.009). However, the mean BMI, although higher in the success group, was not significantly different (27.3±4.7 vs. 23.85±2.9; p=0.088).The majority of patients were non smokers (68.4% vs. 57.1%; p=0.661) and non drinkers (73.7% vs. 71.4%; p=1.000), and most had no comorbidities (68.4% vs. 85.7%; p=0.629), though none of these factors were statistically significant.

Factors related to mandibular defect classification found that Class II and IIc had the highest success rate (52.6% vs. 28.6%), followed by Class I (31.6% vs. 28.6%) and Class III (15.8% vs. 42.8%), respectively. The majority of mandibular defects in the success group did not involve the symphysis (68.4% vs. 28.6%), whereas the majority of failures did involve the symphysis (31.6% vs. 71.4%).The total bone graft length in the successful group was slightly shorter than in the failed group (8.8±1.5 cm vs. 9.1±2.2 cm), though this difference was not statistically significant (p=0.688).The majority of reconstructions were immediate (73.7% vs. 57.1%), followed by delayed reconstruction (26.3% vs. 42.9%), though this difference was also not statistically significant (p=0.635). There was a higher usage of 2.4-mm locking reconstruction plates (68.4% vs. 71.4%) compared to 2.7-mm non locking plates (31.6% vs. 28.6%), though again, there was no significant difference (p=1.000).

The duration of MMF in the success group was significantly longer than in the failed group (34.3±14.4 days vs. 8.6±15.7 days; p=0.005). The duration of plate stabilization, however, was not significantly different between the two groups (198.4±27.6 days vs. 195.7±39 days; p=0.841). Regarding bone graft intersegment union, complete bone union was achieved by designing a long segmental graft block (≥ 4 cm), as measured by panoramic radiographs, and by using the size of the reconstruction plate as a reference. This outcome was statistically more common in the success group compared to the failure group (84% vs. 14.3%; p=0.002). Of the seven failed cases, two were associated with postoperative localized infections, and one required complete graft removal (Table 2).

The multivariable risk difference regression analysis identified six variables that predicted prognostic success factors (Table 3). These factors included female gender (RD -12.3; 95% CI -35.5, 10.9; p=0.299), age (RD 0.15; 95% CI -0.6, 0.9; p=0.672), body weight (RD -0.01; 95% CI -0.7, 0.7; p=0.957), and height (RD -5.9; 95% CI -2.4, 1.2; p=0.529). The factors most significantly influencing graft stability and incorporation were MMF time of at least 21 days (RD 63.0; 95% CI 33.1, 93.0; p<0.001) (Figure 4) and long segmental block graft design (51.3%; 95% CI 16.9, 85.7; p<0.003). An important clinical factor, although statistically insignificant, was the recommended duration of plate stabilization, which should be between 172 and 232 days before plate removal (Figure 5).

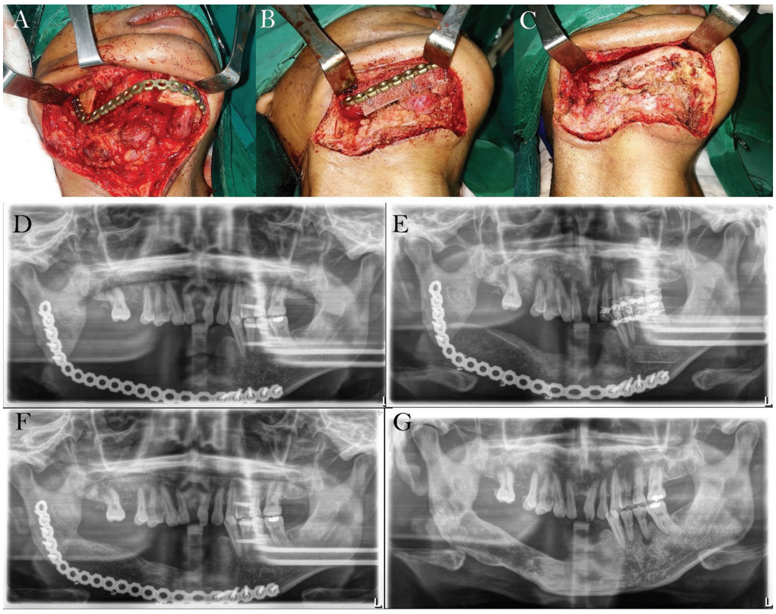

Figure 2: A. A 2.4-mm locking-type reconstruction plate stabilizes the mandibular defect after tumor resection.
B. A delayed nonvascularized iliac bone graft was performed 72 days after tumor resection.
C. A nonvascularized bone graft was performed 185 days after plate removal.
D. The radiographic examination reveals a 2.4-mm locking-type reconstruction plate that stabilizes the mandibular defect following tumor resection.
E. The radiographic examination indicates that a delayed non vascularized iliac bone graft was conducted 72 days following tumor resection.
F. The radiographic examination demonstrates incorporation of the iliac bone graft at 178 days.
G. The radiographic examination revealed the transplanted bone at 242 days.

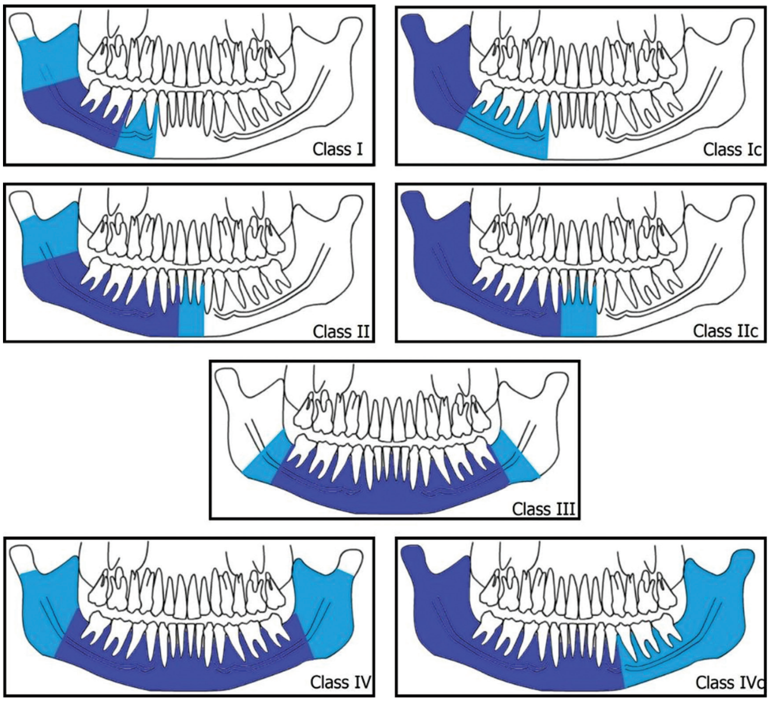

Figure 3: Brown *et al*.'s classification of mandibular defects.[13] Mean defect size (Dark blue); total extent of mandibular defect (blue).

Table 1: Preoperative demographic and intraoperative information.

Characteristics	Success (n=19)		Failure (n=7)		*p*-value
	n	(%)	n	(%)	
Gender					
Male	11	57.9	5	71.4	0.668
Female	8	42.1	2	28.6	
Age(year), mean±SD	36.4	(±12.3)	44.1	(±9.9)	0.146
Body weight(kg), mean±SD	74.3	(±13.6)	59.3	(±6.2)	0.010
Height(cm), mean±SD	164.9	(±5.9)	157.3	(±6.9)	0.009
BMI, mean±SD	27.3	(±4.7)	23.85	(±2.9)	0.088
Smoking					
Yes	6	31.6	3	42.9	0.661
No	13	68.4	4	57.1	
Alcohol consumption					
Yes	5	26.3	2	28.6	1.000
No	14	73.7	5	71.4	
Comorbidities					
No	13	68.4	6	85.7	0.629
Hypertension	3	15.8	0	0	0.540
Diabetes mellitus	2	10.5	0	0	1.000
Hypothyroidism	1	5.3	0	0	1.000
Adrenal insufficiency	0	0	1	14.3	0.269
Brown classification of mandibular defects					
Class I and Ic	6	31.6	2	28.6	1.000
Class II and IIc	10	52.6	2	28.6	0.391
Class III	3	15.8	3	42.8	0.293
Class IV and IVc	0	0	0	0	0
Symphysis involvement	6	31.6	5	71.4	0.095
No symphysis involvement	13	68.4	2	28.6	
Total bone graft length(cm),mean±SD	8.8	(±1.5)	9.1	(±2.2)	0.688
Total bone graft length of mandibular defect					
Class I and Ic (cm),mean±SD	9.1	(±1.7)	10.7	(±0.5)	0.196
Class II and IIc (cm),mean±SD	9.1	(±1.3)	9.6	(±3.9)	0.402
Class III (cm),mean±SD	7.1	(±0.6)	7.7	(±1.3)	0.011
Class IV and IVc (cm),mean±SD	0	0	0	0	0
Stage of reconstructions					
Immediate reconstruction (Primary)	14	73.7	4	57.1	0.635
Delayed reconstruction (Secondary)	5	26.3	3	42.9	
Graft stabilization methods					
2.4-mm. locking type of reconstruction plate	13	68.4	5	71.4	1.000
2.7-mm. non locking type of reconstruction plate	6	31.6	2	28.6	

Abbreviations: SD, standard deviation

Table 2: Postoperative information.

Characteristics	Success (n=19)		Failure (n=7)		*p*-value
	n	(%)	n	(%)	
Maxillomandibular fixation time (days), mean±SD	34.3	(±14.4)	8.6	(±15.7)	0.005
Plate stabilization time (days), mean±SD	198.4	(±27.6)	195.7	(±39)	0.841
Long segmental block graft design union (≥4 cm)					
Complete bone union, n(%)	16	84.2	1	14.3	0.002
Incomplete bone union, n(%)	3	15.8	6	85.7	
Graft infection, n(%)	0	0	2	28.57	0.065
Total graft loss, n(%)	0	0	1	14.29	0.269

Abbreviations: SD, standard deviation

Table 3: Multivariable risk difference regression analysis.

Characteristics	Success (n=19) n (%)	Failure (n=7) n (%)	Adjust RD (%)	95% CI	*p*-value
Female (n, %)	8 (42.1)	2 (28.6)	-12.3	-35.5, 10.9	0.299
Age (year)	36.4 (±12.3)	44.1 (±9.9)	0.15	-0.6, 0.9	0.672
Body weight (kg)	74.3 (±13.6)	59.3 (±6.2)	-0.01	-0.7, 0.7	0.957
Height (cm)	164.9 (±5.9)	157.3 (±6.9)	-5.9	-2.4, 1.2	0.529
MMF time (day)	34.3 (±14.4)	8.6 (±15.7)	-	-	-
MMF time ≥21 days	-	-	63.0	33.1, 93.0	<0.001
Long segmental block graft design (n,%)	16 (84.2)	1 (14.3)	51.3	16.9, 85.7	0.003

Abbreviations: CI, Confident interval; RD, Risk difference

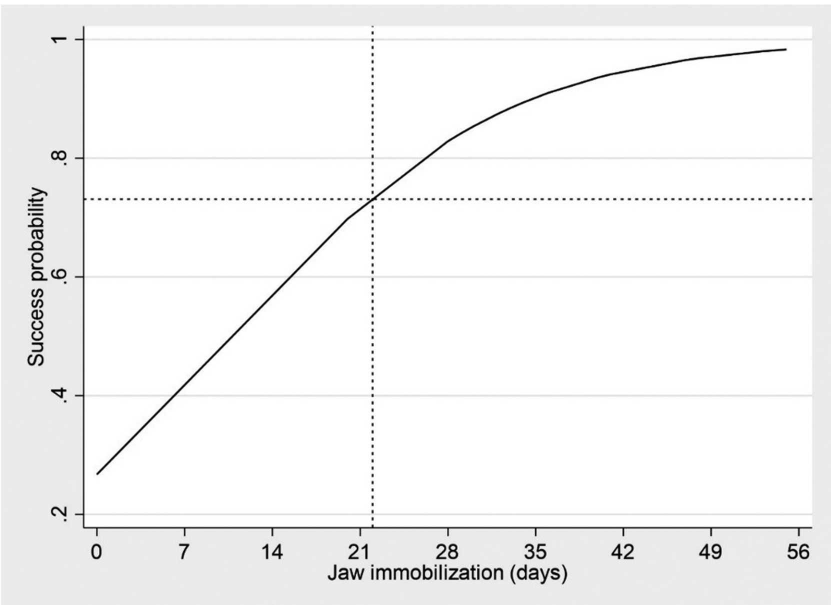

Figure 4: The graph illustrates the probability of success, indicating that the duration of jaw immobilization with maxillomandibular fixation should be a minimum of 21 days.

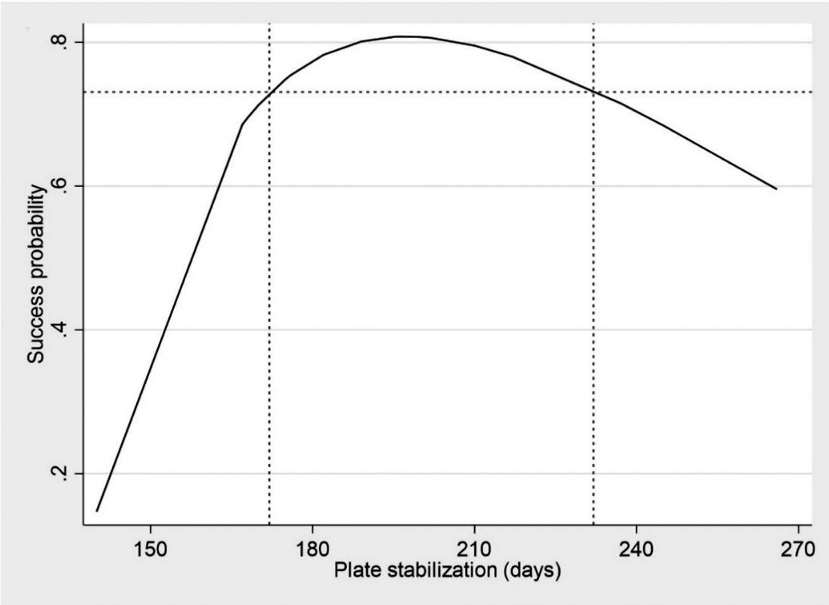

Figure 5: The graph illustrates the probability of success, suggesting that the optimal duration for plate stabilization should range between 172 days and 232 days.

Discussion

Nonvascularized autogenous bone grafting for mandibular segmental defect reconstruction is a challenging operation, often performed following corrective surgery for benign neoplasms, trauma, or infection. The benefits of this technique include less donor site morbidity, reduced operation time, and shorter hospital stays compared to vascularized bone graft techniques. Therefore, NVBG is a viable option for mandibular reconstruction.

Generally, the factors that affect surgical technique and graft incorporation success include the quality of soft tissue coverage without infection, non irradiated tissue, and graft stabilization techniques. However, it is essential to study other biomechanical factors that play a significant role in successful bone graft incorporation to improve clinical practice guidelines and treatment outcomes.

The purpose of this study was to identify the variables affecting the success or failure of nonvascularized iliac bone grafts in subjects who underwent mandibular reconstruction over an 11-year period. Based on this research, the success rate of non vascularized iliac crest bone grafting for mandibular reconstruction was 73.1%. We used the autogenous corticocancellous technique to obtain cancellous bone cells and rigid cortex for stabilization.(14) The results of this study were similar to previous studies, which found varying success rates for NVBGs: 69%(15), 76%(16), 87.6%(1), and 90%.(12) Patient factors that influenced success in this study included weight (p=0.010) and height (p=0.009), while no significant differences were found for gender (p=0.668), age (p=0.146), BMI (p=0.088), and comorbidities (p=0.629).

According to a retrospective study by Schileve *et al*.,(17) gender and age were not associated with bone graft success rates. However, no studies have shown a correlation between weight, height, and bone graft success. Most patients in this study were non smokers and non drinkers, which aligns with several previous studies that reported lower success rates in smokers due to a compromised pool of osteoprogenitor cells at the recipient site.(3,5,9,18)

Regarding the classification of mandibular defects Brown *et al*.,(13), the majority of successes were observed in Class II (52.6%) and Class I (31.6%) defects, located in the lateral mandible. These regions had higher success rates than defects involving the symphysis or central areas. Moura *et al*.,(1) reported lower complication rates in lateral defects, and graft incorporation of NVBGs was comparable to that of VBGs. On the contrary, defects involving the symphysis or extending across the midline of the mandible can lead to complications such as wound dehiscence, plate exposure, and graft infection.(4,8,23)

Due to the limitations of sample size, we found that the mean length of the total bone graft in the success group was shorter than in the failure group, but we were still unable to determine the optimal graft length for success. Pogrel *et al.*,[16] found that grafts 6 cm or shorter had a 17% failure rate, while grafts over 12 cm had a 75% failure rate. They recommended NVBGs for secondary mandibular reconstruction for defects less than 9 cm in length. Foster *et al*.,[15] reported success rates of 75% for defects smaller than 6 cm, while defects measuring 6-10 cm and 10-14 cm had lower success rates of 46% and 40%, respectively. Although previous studies have shown lower success rates for grafts longer than 6 cm, it remains controversial whether NVBGs should be used in defects greater than 6 cm, especially in patients with sufficient soft tissue coverage. Other factors such as graft stability and rigid fixation types also promote bone healing.[1,9-12]

A comparison of reconstruction stages in this study found that most patients underwent primary reconstruction, while those with large tumors or tumors involving the symphysis region received secondary bone grafts. However, no correlation was found between reconstruction stage and success rate. Generally, primary reconstruction is preferred as it allows for cosmetic and functional restoration after ablative surgery in the same episode, facilitating early bone union and rehabilitation. The advantages of this procedure include abundant vascular supply to the recipient site, reduced scar formation, and fewer surgeries, which benefit the patient's psychological well-being. However, the intraoral approach increases the risk of infection due to oral bacterial contamination.[16,19] In contrast, secondary procedures, while associated with compromised vascularity due to scar tissue, can be successful with NVBGs. Studies have reported success using secondary or delayed reconstruction via extraoral approaches, typically performed 6-8 weeks after tumor resection to prevent oral contamination.[9,16,20,21] The reconstruction plates used in this study were 2.4-mm locking types and 2.7-mm non locking types, with no significant differences in success between the two types. Kim *et al.,*[22] found that locking reconstruction plates were associated with fewer complications than non locking plates in patients undergoing mandibular resection for head and neck cancer.

In addition to rigid reconstruction plates, maxillomandibular fixation (MMF) for jaw immobilization is essential for success. We found that MMF for at least 21 days increased the success rate by up to 63%. Tidstrom *et al.,*[20] reported MMF durations of 1-6 weeks in their study, and Gadre *et al*.[8] found an 88.5% success rate with 10-12 days of MMF. We recommend a minimum of 21 days of MMF to enhance graft stability and reduce micro-movements that could disrupt angiogenesis and creeping substitution. The evaluation of mono-cortico-cancellous bone graft union in this study showed that the segmental block grafts longer than or equal to 4 cm achieved greater stability than shorter grafts. However, several reports indicate that bone grafting demonstrates success in cases where the total bone graft size is less than or equal to 6 cm.[15,16] In addition, mechanical stability is crucial for revascularization and cellular differentiation at the recipient site. Granulation tissue and fibrosis may form between the graft and recipient bone when stabilization is insufficient.[5] Although reconstruction plates provide significant stability, some studies suggest plate removal at six months to prevent stress shielding.[8,16]

Conclusions

Mandibular segmental defect reconstruction using autogenous nonvascularized iliac bone grafts remains a useful option for non irradiated recipient sites. Factors influencing graft stability, such as reconstruction plates with maxillomandibular fixation and long block bone graft design, can improve clinical outcomes, reduce bone resorption, and maintain mandibular continuity. These findings can help inform clinical practice guidelines. However, due to the limitations of this study, further research and systematic data collection are needed.

List of abbreviations used

AICBG	Anterior iliac crest bone graft
CI	Confident interval
DCIA	Deep circumflex iliac artery free flap
FFF	Fibula free flap
MMF	Maxillomandibular fixation
NVBG	Nonvascularized bone graft
RD	Risk different
SD	Standard deviation
VBG	Vascularized bone graft

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Conflicts of Interest

The author declares no potential conflicts of interest related to this research.

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