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Clinical evaluation of a novel cotton-like β-tricalcium phosphate, poly-L-lactic acid, and polyglycolic acid bone graft material for jawbone defects following cystectomy

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Abstract (J Korean Assoc Oral Maxillofac Surg 2026;52:128-138)

Objectives: Jawbone defects following cystectomy for cysts of the jaw may cause postoperative complications such as pathological fractures and secondary infections. Therefore, different bone-grafting procedures have been developed. Novel cotton-like bone graft material composed of β-tricalcium phosphate, poly-L-lactic acid, and polyglycolic acid (β-TCP/PLLA/PGA) has handling properties, three-dimensional shapeability, and bone forming ability, and has potential clinical utility for bone formation. However, no studies have evaluated the clinical outcomes of the novel β-TCP/PLLA/PGA in patients of oral and maxillofacial surgery. Thus, we evaluated the usefulness of β-TCP/PLLA/PGA in bone formation within jawbone defects following cystectomy.

Patients and Methods: 28 patients (19 males and 9 females; mean age: 47.5 years) who visited the Department of Oral and Maxillofacial Surgery, Shimane University Hospital, between November 2022 and April 2024 were included. They underwent cystectomy for cysts of the jaw (maxilla or mandible) and were grafted with β-TCP/PLLA/PGA. All excised cyst were submitted for histopathological examination. Patient demographics, clinical data, and computed tomography (CT) images were retrospectively evaluated to assess the defect dimensions, CT values, and bone continuity of the jawbone defects. Data on postoperative complications were obtained from medical records.

Results: Among the 28 cystic lesions (6 maxillary and 22 mandibular jaw cases), 27 were odontogenic cysts (26 odontogenic cysts and 1 orthokeratinized odontogenic cyst), and 1 was a non-odontogenic cyst (nasopalatine duct cyst). Both long- and short-axis lengths of the jawbone defect revealed a significant decrease at 6 months postoperatively compared with the preoperative and 1-month postoperative values. The CT values were significantly increased from 1 month to 6 months postoperatively ($P<0.05$). At 6 months postoperatively, 39.3% of the patients achieved full bone continuity. No serious adverse events were observed.

Conclusion: β-TCP/PLLA/PGA demonstrated excellent handling characteristics and clinical safety as a novel cotton-like bone graft material for jawbone defects following cystectomy.

Key words: Bone graft, Synthetic graft materials, Benign pathology, Odontogenic cysts, Jawbone defect

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I. Introduction

Intrabony cysts of the jaw are common benign cystic lesions occurring in the oral and maxillofacial areas. These lesions are classified into odontogenic cysts, which arise from the epithelium associated with tooth development, and non-odontogenic cysts, which originate from the epithelial remnants and are unrelated to odontogenesis. Regarding the distribution of cysts of the jaw, more than 90% are odontogenic cysts, among which 58.6% are radicular cysts, 17.9% are dentigerous cysts, and 13.3% are odontogenic keratocysts[1]. In contrast, nasopalatine duct cysts and median maxillary cysts are the most common non-odontogenic cysts. These cysts tend to enlarge over time, leading to jawbone expansion, tooth displacement, malocclusion, and progressive thinning of the jawbone due to bone resorption. In addition, infections

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of the cystic lesions can lead to pain, swelling and any related discomfort[1].

Treatment for the cysts of the jaw vary from observation, marsupialization, cystectomy, and jawbone resection. The final treatment option is selected depending on cyst size, histological type including benign or any possibility of recurrence tendency, and patient's clinical factors[2]. However, most of the cases, cystectomy is decided for the choice for first treatment[3]. Postoperative wound management may involve either primary closure or secondary healing. Nevertheless, restoration of jawbone defects following cystectomy remains a clinical challenge because healing is often slow and incomplete. After cystectomy jawbone regeneration often requires a prolonged healing period, and incomplete bone formation is frequently observed[4]. Thus, residual jawbone defects may predispose patients to postoperative complications such as pathological fractures, delayed wound healing, and secondary infections. Therefore, treatments such as autografts, xenografts, allografts, and synthetic bone substitutes have been conducted depending on the defect volume, shape under consideration of patient clinical factors[5].

Bone graft materials should fulfill several requirements, including unlimited availability without donor-site morbidity, promotion of osteogenesis, absence of a host immune response, rapid revascularization, stimulation of osteoinduction, support of osteoconduction, and complete replacement with bone of comparable quantity and quality[6-8]. Autologous bone remains the gold standard for bone grafting and has been employed for over a century, with approximately two million autografts performed annually worldwide[9]. This preference is largely attributed to its superior mechanical strength and biological properties, along with the absence of an immune response. However, autologous bone graft causes complications at the donor site such as postoperative pain, sensory impairment, and risk of surgical site infection, and most importantly leads to a limited bone supply. Furthermore, certain autologous bone grafting procedures, such as iliac bone grafting, require general anesthesia and are limited to the patients in good general condition[10]. Therefore, alternative bone graft materials are being developed to overcome these limitations of the autologous bone. Xenogeneic bone grafts have been widely used because of their stable supply, ease of storage, and favorable osteoconductive properties[11]. However, concerns regarding immunological reactions have restricted their use in clinical settings[12]. In contrast, allogeneic bone grafts avoid xenogeneic antigen-related immune reactions and are considered a suitable alternative[13]. Demineralized bone matrix, a representative allogeneic graft material, exhibits osteoinductive and osteoconductive properties; however, it also has limitations related to immunologic sensitization, loss of osteogenic potential during sterilization, and handling characteristics[10,14-16]. Accordingly, the limitations inherent to biological graft materials have driven growing interest in the development of synthetic bone substitutes as practical and reproducible alternatives[6-8].

Synthetic bone substitutes include calcium phosphate-based materials, such as hydroxyapatite (HA) and β-tricalcium phosphate (β-TCP), and composite materials incorporating biodegradable polymers, such as β-TCP/poly-L-lactic acid/polyglycolic acid (β-TCP/PLLA/PGA)[8,17]. HA exhibits excellent biocompatibility and osteoconductivity but shows slow resorption and incomplete replacement by new bone[18,19]. In contrast, β-TCP has been widely used because of its favorable biocompatibility, osteoconductivity, and bioresorbability and has been shown to support new bone formation in experimental model[17,20,21]. Furthermore, β-TCP is regarded as a resorbable bone substitute because it is gradually resorbed and replaced by newly formed bone *in vivo* through physiological bone remodeling[20]. However, β-TCP in its granular form has limited handling properties and poor moldability, possibly restricting its application in complex or irregularly shaped bone defects. Moreover, its relatively high material cost should be considered[22,23].

PLLA and PGA have been incorporated to improve the handling characteristics of β-TCP. In addition, electrospinning technology has been applied to produce a cotton-like β-TCP/PLLA/PGA bone graft material with enhanced three-dimensional shapeability[24]. A cotton-like β-TCP/PLLA/PGA bone graft material may be useful in cases requiring high moldability, such as defects of the maxillofacial bones, which have complex three-dimensional anatomy. Furthermore, because a cotton-like β-TCP/PLLA/PGA bone graft material was approved for coverage under the Japanese national health insurance system for treating jawbone disorders since 2024, its clinical use has increased. Our previous basic studies demonstrated that cotton-like β-TCP/PLLA/PGA exhibits favorable osteoconductivity, handling properties, and three-dimensional conformability, and achieves bone formation comparable to that of conventional β-TCP[25,26]. The combination of these biological and handling advantages indicates that β-TCP/PLLA/PGA may represent a promising bone graft material for clinical application in orthopedic, oral and maxillofacial surgery fields. However, no studies have evaluated the clinical outcomes of β-TCP/PLLA/PGA in patients within

the field of oral and maxillofacial surgery. In this study, we conducted a single-center, retrospective, observational study to evaluate the clinical outcome of a cotton-like bone graft material for jawbone defects following cystectomy of the jaw.

II. Patients and Methods

1. Patients and study design

A total of 33 patients who underwent bone grafting with β-TCP/PLLA/PGA following cystectomy between November 2022 and April 2024 were included in this study. Patient eligibility criteria were as follows: (1) Patients who visited the Department of Oral and Maxillofacial Surgery, Shimane University Hospital, Shimane University, Izumo, Japan, were diagnosed as having cysts of the jaw (maxilla or mandible) on clinical presentation and imaging findings. (2) Patients who underwent cystectomy and grafted with β-TCP/PLLA/PGA for jawbone defects. (3) Patients with jawbone defects following cystectomy treated with a single package (0.2 g) of β-TCP/PLLA/PGA. From a clinical perspective, the included jawbone defects following cystectomy had a long axis length of approximately 10 to 30 mm. (4) Patients who were followed-up observation for at least 6 months postoperatively, and (5) Patients who underwent computed tomography (CT) imaging at 1 month and 6 months postoperatively. Biopsy with histopathological examination was performed for all cystic lesions. Exclusion criteria were as follows: (1) patients who received additional bone graft materials other than β-TCP/PLLA/PGA, (2) patients with systemic bone metabolic disorders, (3) patients with systemic immunodeficiency, and (4) patients using bone-modifying drugs. This study was conducted with approval from the Medical Research Ethics Committee, Shimane University Faculty of Medicine (approval number: 20240506–1). All procedures were performed in accordance with the principles of the Declaration of Helsinki. This study was designed as a single-center retrospective observational study.

2. Materials

β-TCP/PLLA/PGA, commercially available as ReBOSSIS-MT (ORTHOReBIRTH), is an electrospun cotton-like bioresorbable material composed of 70% β-TCP and 30% PLLA/PGA by weight and was used in this study.(Fig. 1. A) β-TCP particles with a size of 1-5 μm in diameter were interspersed in PLLA/PGA fibers. The electrospun material was fabricated as follows. A specific amount of materials mentioned above was melted, and meticulous kneading was performed to create a homogenous mixture. Next, chloroform was added to the mixture, and subsequent electrospinning was performed at 25 kV to generate cotton-like fibers. Each 0.2 g of the material was precisely measured, sterilized, and packed into sep-

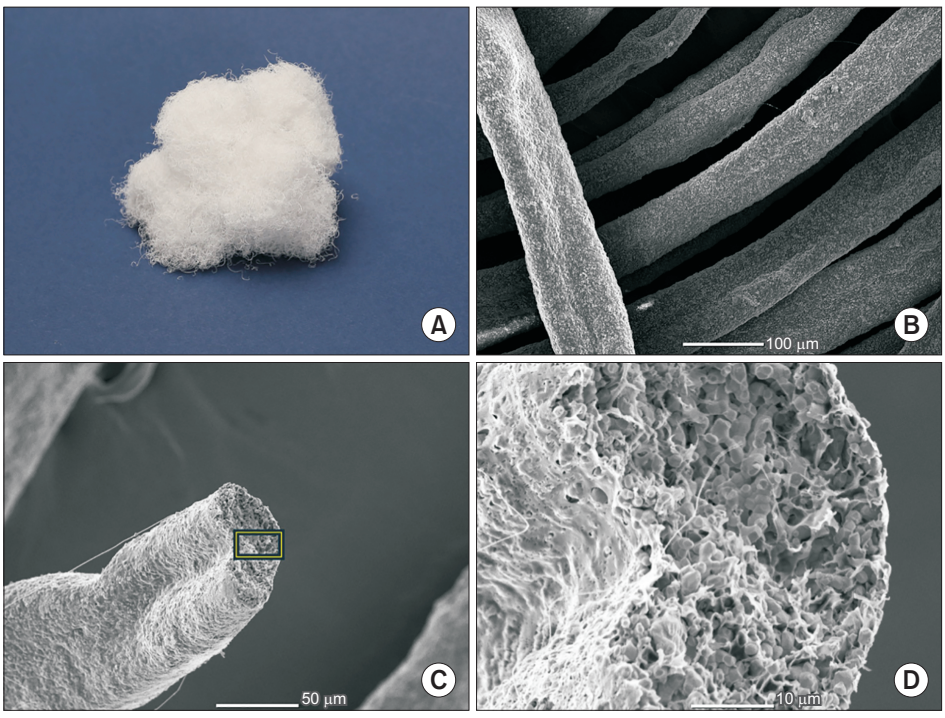


Fig. 1. Image (A) depicts the macroscopic appearance and structure of the β-tricalcium phosphate, poly-L-lactic acid, and polyglycolic acid (β-TCP/PLLA/PGA) electrospun nanobiomaterial. Denote the scanning electron microscopy images of β-TCP/PLLA/PGA electrospun cotton-like structured nanobiomaterial in (B) ×200. The rectangle indicates the region enlarged in Fig. 1. D (C) (×400), and (D) ×2,000 magnifications, respectively.
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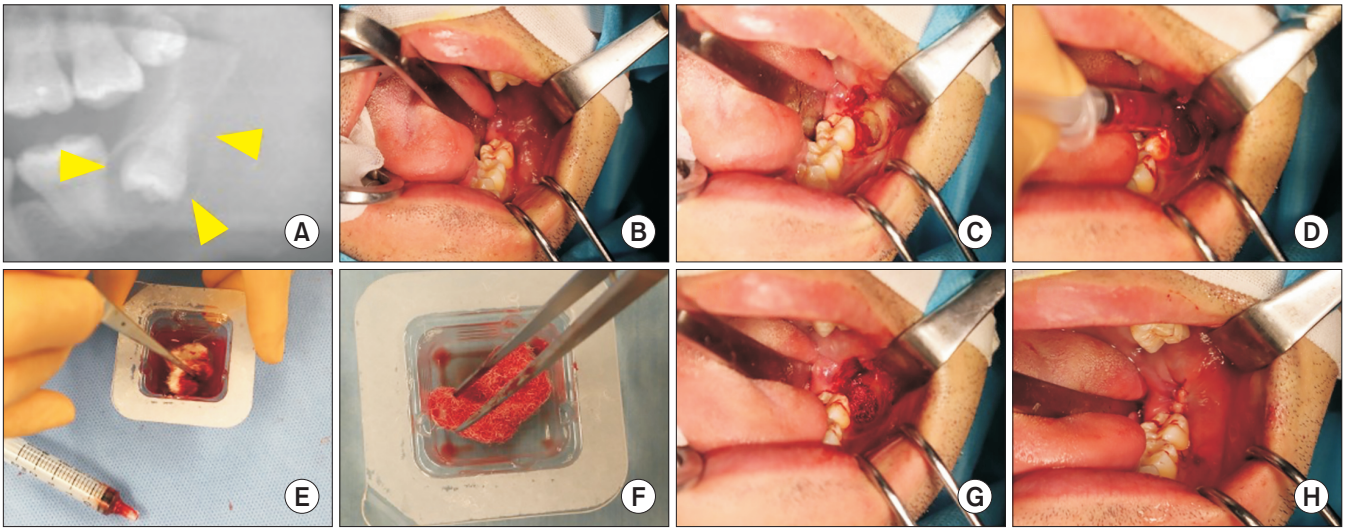


Fig. 2. Surgical procedure of β-tricalcium phosphate, poly-L-lactic acid, and polyglycolic acid (β-TCP/PLLA/PGA): A. Left mandibular bone cyst. B. Indication of surgical site. C. Tooth extraction and cyst of the jaw removal. D. Blood collection. E. Mixing blood with β-TCP/PLLA/PGA. F. β-TCP/PLLA/PGA after formation. G. Filling the jawbone defect with β-TCP/PLLA/PGA. H. Complete closure of surgical site.
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arate containers using ORTHOReBIRTH. Scanning electron microscopy images of β-TCP/PLLA/PGA nanobiomaterial are depicted in Fig. 1. B-1. D. An image of the β-TCP/PLLA/PGA material was provided by ORTHOReBIRTH.

3. Surgical procedure of cystectomy and β-TCP/PLLA/PGA graft

The β-TCP/PLLA/PGA material was grafted according to the manufacturer's instructions. Preoperative imaging was performed to assess the shape and location of the cysts of the jaw (Fig. 2. A), which were clearly identified and marked. (Fig. 2. B) The involved teeth were extracted when necessary, and the cysts of the jaw were completely removed by cystectomy.(Fig. 2. C) Subsequently, 1.6 mL of blood was collected from the surgical site.(Fig. 2. D) The collected blood was injected into the β-TCP/PLLA/PGA material and thoroughly mixed to ensure uniform impregnation.(Fig. 2. E) Afterward, the β-TCP/PLLA/PGA was shaped to match the morphology of the jawbone defect (Fig. 2. F) and was grafted at the defect site.(Fig. 2. G) Finally, the surgical site was primarily closed using standard suturing techniques.(Fig. 2. H) Postoperative follow-up evaluations were performed 1 month and 6 months after surgery.

4. Evaluation of bone formation in defects by computed tomography analysis

CT examinations were performed 1 month and 6 months postoperatively using a multidetector CT scanner (Aquilion ONE Vision Edition; Canon) under standardized imaging conditions (tube voltage: 120 kVp; tube current: 300 mA). Images were reconstructed with a slice thickness of 0.5 mm. Bone formation within the jawbone defects was assessed using three evaluation parameters: long- and short-axis lengths of the defect, CT values, and bone continuity. CT-based assessments were independently performed and validated by two evaluators (T.D. and M.S.) to ensure reproducibility and reliability.

1) Long- and short-axis lengths of the jawbone defect

The area of the jawbone defect was calculated from the preoperative, 1 month postoperative, and 6 months postoperative CT images. The slice demonstrating the largest defect area was then selected for analyses. If the preoperative CT displayed a cyst containing teeth, the area was calculated, including the teeth, and the slice image with the maximum area was selected. For the selected slice image, the longest (long axis) and shortest axes (short axis) of the jawbone defect were determined, and the length (mm) was measured[27].(Fig. 3. A)

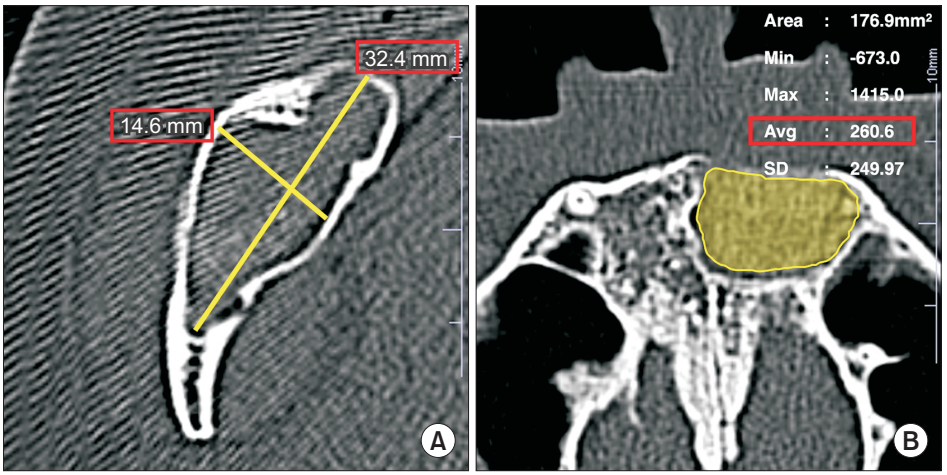


Fig. 3. A. Example of measuring the long axis and short axis of the jawbone defect. B. Example of measuring the computed tomography values of the jawbone defect. The yellow area represents region of interest. (Avg: average, SD: standard deviation)
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2) Computed tomography value of the jawbone defect

The evaluation was performed using the same CT images that were used for the measurement of the long- and short-axis lengths of the jawbone defect. On each slice, a region of interest (ROI) was manually drawn 1 mm inward from the surrounding bone[27].(Fig. 3. B) The CT value of the ROI was measured in Hounsfield units (HU). The same procedure was followed to set the ROI and measure the CT value (HU) on slice images obtained by shifting the axial CT image up and down by 2 mm. The average of three CT values (HU) from the center and up/down regions was calculated and adopted as the patient's average CT value (HU). The evaluation method was validated by two oral surgeons before implementation.

3) Bone continuity

The evaluation was performed using the same CT images that were used for the measurement of the long- and short-axis lengths of the jawbone defect. On that slice image, the continuity of the bone surrounding the jawbone defect was evaluated using a three-point scoring system[28,29]. Score 0 indicated bone continuity involving less than 50% of the grafted area; Score 1 indicated bone continuity involving more than 50% but less than 100% of the grafted area; and Score 2 indicated complete circumferential bone continuity around the grafted area. Examples of bone continuity with scores of 1 and 2 are shown in Fig. 4, respectively[29].

5. Clinical complications within 6 months

Postoperative complications were defined as follows: (1) surgical site infection (pain, redness, swelling, or presence of pus at the surgical site)[30], (2) wound dehiscence (reopening of the wound site with exposure of the underlying mucosa or bone), and (3) hypoesthesia (presence of reduced sensation, including decreased tactile sensation or perception), which was subjectively assessed based on patient reports during follow-up[31].

6. Statistical analysis

The Shapiro–Wilk test was performed to assess normality of the data. Descriptive statistics were used for patient clinical factors data, cyst size at each measurement, CT values, bone continuity, and presence of postoperative infection. Continuous variables are expressed as mean (standard deviation) or median (interquartile range) based on data normality. Categorical variables are summarized as counts and percentages. The Friedman test was performed to determine temporal changes in the major and minor axis diameters of the jawbone defects. Multiple comparisons (Bonferroni correction) were performed for each item. The Wilcoxon signed-rank test was performed for CT values. Interobserver reliability of the measurements was assessed by calculating the intraclass correlation coefficient (ICC). All the statistical analyses were performed using IBM SPSS Statistics ver. 29.0 (IBM). Two-tailed *P*-values were calculated for all analyses with the alpha level of significance set at 0.05.

III. Results

1. Patient demographic data

Among 33 patients who underwent bone grafting with β-TCP/PLLA/PGA following cystectomy, 28 patients (19 males and 9 females; mean age: 47.5 years; 6 maxillary and

22 mandibular intrabony cyst cases) with complete clinical follow-up were included. Of the 28 cystic lesions, 27 were odontogenic cysts and 1 was a non-odontogenic cyst. Among the odontogenic cysts, 26 were dentigerous cysts and 1 was an orthokeratinized odontogenic cyst, while the non-odontogenic cyst was a nasopalatine duct cyst. Detailed patient demographic characteristics, including age, sex, and pathological diagnosis, are summarized in Table 1.

Table 1. Patient demographics and clinical characteristics

Item	Value
Age (yr)	47.5±19.6
Sex	
Male	19 (67.9)
Female	9 (32.1)
Pathological diagnosis	
Odontogenic cysts	
Dentigerous cysts	26 (92.8)
Orthokeratinized odontogenic cyst	1 (3.6)
Non-odontogenic cysts	
Nasopalatine duct cyst	1 (3.6)

Values are presented as mean±standard deviation or number (%).
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2. Long and short axis lengths of jawbone defects

The long axis lengths of the jawbone defect displayed a statistically significant decrease at 6 months postoperatively compared with the preoperative values and those at 1 month postoperatively (P<0.05).(Fig. 5. A) In addition, the short-axis lengths of the jawbone defect showed a statistically significant decrease at 6 months postoperatively compared with the preoperative values and those at 1 month postoperatively (P<0.05).(Fig. 5. B) Preoperatively, the maximum and minimum long-axis lengths of jawbone defects were 25.8 and 10.3 mm, respectively, and the maximum and minimum short-axis

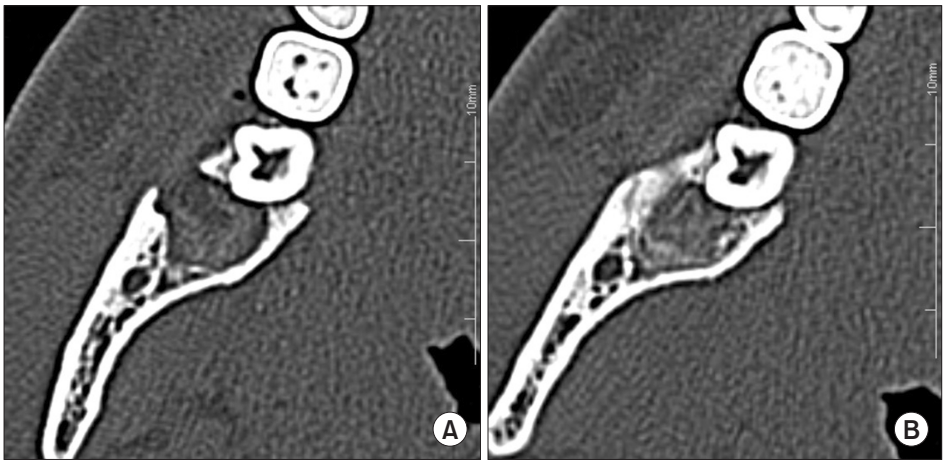


Fig. 4. Evaluation of bone continuity: A. Bone continuity Score 1. B. Bone continuity Score 2.
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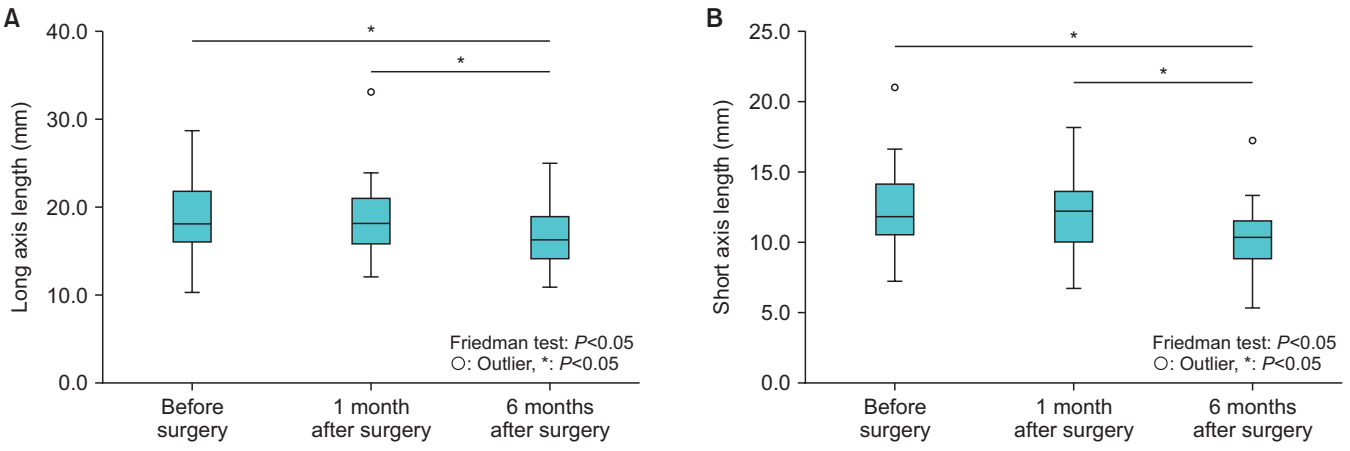


Fig. 5. Changes in length of the jawbone defect using the Bonferroni correction followed by Friedman test for multiple comparisons: A. Long axis length of the jawbone defect. B. Short axis length of the jawbone defect.
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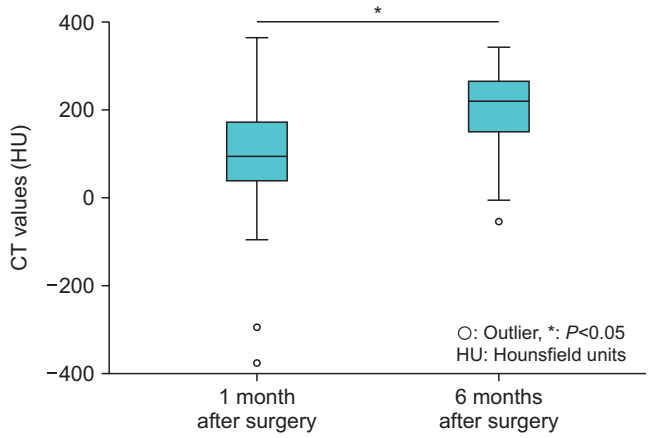


Fig. 6. Changes in computed tomography (CT) values at 1 and 6 months postoperatively using the Wilcoxon signed-rank test.
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lengths were 21.1 and 7.3 mm, respectively. At 1 month postoperatively, the long-axis lengths were 33.3 mm (maximum) and 12.1 mm (minimum), and the short-axis lengths were 18.2 and 6.8 mm, respectively. At 6 months postoperatively, the maximum and minimum long-axis lengths were 25.1 and 11.0 mm, respectively, and the corresponding short-axis lengths were 17.3 and 5.4 mm, respectively. The ICC values for long-axis and short-axis measurements were 0.45 and 0.65, respectively.

3. Computed tomography value (HU) of jawbone defects

The CT values (HU) showed a statistically significant increase from 1 month to 6 months postoperatively (P<0.05). (Fig. 6) At 1 month postoperatively, the mean CT value was 78.9 HU. At 6 months postoperatively, the mean CT value increased to 207.4 HU. This represented an approximately 2.6-fold increase during the follow-up period. Interobserver reliability of CT value measurements was assessed using the ICC, which demonstrated excellent agreement (ICC=0.99).

4. Bone continuity

At 1 month postoperatively, all patients showed bone continuity surrounding more than 50% of the graft material (Score 1). However, complete bone continuity was not observed in any patient at this time point. By 6 months postoperatively, 39.3% of the patients had achieved complete bone continuity (Score 2). No patients were classified as Score 0 during the follow-up period, indicating that bone continuity surrounding less than 50% of the graft material was not observed in any case.(Table 2)

Table 2. Descriptive statistics for bone continuity assessment at 1 month and 6 months postoperatively

Score	Number (%)	
	One month follow-up	Six months follow-up
0	0 (0)	0 (0)
1	28 (100.0)	17 (60.7)
2	0 (0)	11 (39.3)

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Table 3. Descriptive statistics for clinical complications within 6 months

Category	Six months after surgery
	Number (%)
None	20 (71.4)
Surgical site infection	3 (10.7)
Wound dehiscence	1 (3.6)
Paresthesia	4 (14.3)

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5. Clinical complications

Surgical site infection and wound dehiscence occurred in four patients (14.3%) postoperatively. All cases were successfully managed conservatively with irrigation and/or administration of penicillin-based antibiotics, and the symptoms resolved within 1 week. Paresthesia was observed in four patients and improved following postoperative vitamin supplementation. No postoperative complications or adverse events were observed in the remaining 20 patients during the follow-up period.(Table 3)

IV. Discussion

This retrospective study suggested that β-TCP/PLLA/PGA may be a useful bone graft substitute with a favorable safety profile. Both the long- and short-axis lengths of the jawbone defect, used as primary outcome measures, demonstrated a significant decrease at 6 months postoperatively compared with the preoperative values and those at 1 month postoperatively. The significant reductions in both long- and short-axis dimensions suggest circumferential radiographic healing within the jawbone defects. Ramanathan et al.[25] reported that the use of electrospun β-TCP/PLLA/PGA composites in rat

jawbone defects promoted bone formation, originating from the marrow, periosteum, and endosteum of the residual bone, with newly formed bone progressing from the periphery toward the center of the defect. The findings of this study are consistent with this healing pattern, and radiographic healing observed was not inconsistent with the findings reported by Ramanathan et al.[25]. Furthermore, Ramanathan et al.[25] demonstrated that circumferential bone formation is a characteristic feature of electrospun β-TCP/PLLA/PGA composites. Circumferential bone formation is believed to be related to the structure of the electrospun material. Electrospinning is a fabrication technique that mimics the three-dimensional extracellular matrix environment within a defect site, thereby promoting cell adhesion, proliferation, and osteogenic differentiation[32]. Glaeser et al.[33] demonstrated that electrospun materials applied in rat models promoted three-dimensional bone healing. Collectively, these findings suggest that electrospun scaffolds facilitate isotropic bone formation by providing a three-dimensional extracellular matrix-like environment. Accordingly, the cotton-like β-TCP/PLLA/PGA bone graft material used in the present study may contribute to more uniform and circumferential healing within jawbone defects[34]. In contrast, a clinical study including 15 patients who underwent fenestration for cysts of the jaw reported that the buccolingual width of the cystic cavity revealed minimal reduction within the first 3 months postoperatively, whereas the vertical reduction progressed consistently from an early stage[35]. This difference in healing patterns suggests that bone formation dynamics vary depending on the treatment modality. Based on these findings, the radiographic healing observed in this study may reflect progressive healing within the jawbone defects. Although these measurements were based on two-dimensional CT slices, the findings may reflect differences in bone healing dynamics compared with those reported for fenestration procedures evaluated using three-dimensional analyses.

The temporal change in the CT values (HU) of bone graft material-filled sites has been widely used as an indicator for evaluating graft resorption and replacement by newly formed bone[36]. Bastami et al.[37] demonstrated a linear correlation between CT values (HU) and the amount of newly formed bone, supporting the use of CT values (HU) as radiographic markers of bone formation. Therefore, the observed increase in the CT values (HU) in the present study may reflect progressive bone formation accompanied by gradual replacement of the grafted material. Increases in CT values (HU) have been reported in animal bone defect models following the application of several bone graft materials, including composite β-TCP and collagen, collagen alone, and β-TCP alone. In particular, micro-CT analysis revealed a significant increase in CT values at 8 weeks postoperatively in defects treated with composite β-TCP and collagen[38]. These results suggest that composite graft materials may facilitate both osteoconduction and subsequent bone deposition at the defect site. Consistent with these previous observations, CT values in this study demonstrated a significant temporal increase during the postoperative follow-up period, suggesting that β-TCP/PLLA/PGA may support progressive healing within jawbone defects rather than merely serving as a space-occupying material. Although CT-based evaluation cannot directly distinguish newly formed bone from the residual graft material, the progressive increase in CT values (HU) over time suggests favorable radiographic healing within the defect site.

Continuity between the bone graft material and residual bone is a radiographic indicator of integration between the grafted site and surrounding bone[39]. From a clinical perspective, improved bone continuity is substantial for reducing the risk of postoperative complications such as pathological fractures[40]. Circumferential continuity between β-TCP/PLLA/PGA and residual bone was confirmed in most cases at 6 months postoperatively in this study. These results suggest that β-TCP/PLLA/PGA may reduce the risk of postoperative complications such as pathological fracture. A previous study in patients with rheumatoid arthritis demonstrated that β-TCP/PLLA/PGA underwent resorption and was replaced by newly formed bone in residual bone tissue, contributing to early postoperative bone healing[40]. Importantly, effective bone formation was observed even in the presence of the inherent bone fragility associated with rheumatoid arthritis[40]. Furthermore, the early achievement of bone continuity observed in this study suggests that β-TCP/PLLA/PGA may have contributed to maintaining the defect space during resorption, thereby providing a stable environment for bone formation.

Although artificial bone graft substitutes generally exhibit high biocompatibility, postoperative infections remain a potential concern that may impair bone formation. Surgical site infection within 6 months after β-TCP/PLLA/PGA grafting was observed in three cases (10.8%). All infections were successfully managed with irrigation and penicillin-based antibiotic therapy, and none of the cases required removal of the graft material. A previous study reported a postoperative infection rate of 36.4% in patients who underwent autogenous bone grafting after the extraction of odontogenic cysts in the

mandibular wisdom tooth region[41]. A comparative analysis of cysts of the jaw revealed that postoperative infection rates differed according to the grafting method: 63.6% in patients treated with autogenous bone grafts, 26.8% in those receiving allografts, and 19.5% in those without bone grafting. These findings indicate that autogenous bone grafting is associated with the highest risk of postoperative surgical site infection[5,42]. Furthermore, a case report of six patients with jawbone defects after cystectomy using calcium phosphate reported no postoperative infections[43]. In the present study, the incidence of postoperative infection after β-TCP/PLLA/PGA grafting was low. These observations suggest that β-TCP/PLLA/PGA, similar to other synthetic bone substitutes, may offer a favorable safety profile and a lower risk of postoperative infection compared with autogenous bone grafting. In addition, β-TCP/PLLA/PGA may support early postoperative healing within jawbone defects, as reflected by defect reduction and improved bone continuity.

In summary, the present findings suggest that β-TCP/PLLA/PGA may be a promising bone graft material for jawbone defects following cystectomy, demonstrating favorable radiographic healing and restoration of bone continuity, while maintaining a favorable safety profile with a low incidence of postoperative complications. The space-maintaining ability during resorption and favorable handling characteristics may provide advantages over β-TCP alone. Nevertheless, further prospective and controlled studies are warranted to confirm these findings and establish their long-term clinical efficacy.

This study had four main limitations. First, this was a single-center retrospective study, limiting its generalizability to other hospitals. However, consistent treatment and evaluation by the same surgeon at a single center ensured homogeneity in assessment methods. Second, the absence of a control group limited the ability to determine whether the observed healing exceeded the natural healing process after cystectomy followed by primary closure or secondary healing to demonstrate the superiority of β-TCP/PLLA/PGA over other grafting materials. Third, the present study evaluated cystectomy jawbone healing using radiographic imaging alone, and it therefore remains unclear whether true bone regeneration occurred within the jawbone defects. However, radiographic assessment is widely used in clinical practice to evaluate healing of jawbone defects because postoperative histological evaluation is generally not feasible. Furthermore, confirming bone regeneration histologically would require an additional surgical procedure, which is generally not performed after successful cystectomy. Fourth, the relatively small sample size may have limited the statistical power of analyses, thus reducing the ability to detect subtle differences. Despite this limitation, consistent and clinically relevant changes were observed in primary outcome measures, supporting a reasonable assessment of treatment effectiveness.

Bone grafting was applied to jawbone defects with a preoperative long axis length of up to approximately 30 mm. Although no previous studies have provided quantitative criteria regarding the size of cysts of the jaw suitable for artificial bone grafting, further investigations are needed to clarify the extent to which synthetic bone substitutes can be safely and effectively applied. In addition, long-term outcomes should be evaluated, and studies with extended follow-up periods are warranted. Furthermore, an increasing number of studies assessing the clinical outcomes of other artificial bone graft materials would be desirable to comparatively evaluate the treatment efficacy among different grafting options.

V. Conclusion

β-TCP/PLLA/PGA demonstrated excellent handling characteristics and clinical safety as a novel cotton-like bone graft material for jawbone defects following cystectomy.

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Authors' Contributions

Y.M. and T.K. conceptualized the study. T.D., M.S., R.M., R.S.O., and H.T. curated the data. Y.M. performed the formal analysis. T.K. acquired the funding. T.D., M.S., R.M., R.S.O., and H.T. conducted the investigation. T.K. developed the methodology. Y.M. and T.K. administered the project. T.D., M.S., R.M., R.S.O., and H.T. provided the resources. Y.M. developed the software. M.F.K. and T.K. supervised the

study. H.T., M.F.K., and T.K. validated the results. T.D. and Y.M. performed the visualization. T.D. and Y.M. prepared the original draft of the manuscript. H.T., M.F.K., and T.K. reviewed and edited the manuscript.

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Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board of Shimane University (approval number: 20240506–1). Patient consent was waived, in accordance with the ethical guidelines for medical and health research involving human individuals in Japan (meets the requirements of Chapter 4, Part 8, Section 8). Simplification of procedures concerning informed consent (Page 32) and followed the provisions of Chapter 4, Part 8, Section 1 B (a) (Page 22).

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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