



Radiographic Observations of Lateral Bone Ridge Augmentation by Guided Bone Regeneration with Biphasic Calcium Sulphate

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Abstract

Objective: To evaluate the radiographic outcomes of guided bone regeneration using Bond Apatite, a calcium sulphate-based bone graft material combined with hydroxyapatite—for lateral bone augmentation. **Method:** Two diabetic patients with lateral bone deficiencies underwent the procedure using the same surgical protocol. Computed tomography radiographs were taken immediately prior to the placement of the Bond Apatite. Follow-up radiographs were taken three months after placement for Patient 1 and seven months after placement for Patient 2. **Results:** Radiographic imaging with cone beam computed tomography (CBCT) revealed significant bone regeneration: Patient 1 exhibited a 4 mm increase in bone thickness and Patient 2 showed a 7 mm increase. The study found that the shape and depth of the bone defects influenced the amount of bone regenerated: deeper, more retentive defects yielded more bone. It was also discovered that bone regeneration occurred beyond the bone defects being filled and that the amount regenerated depended on factors such as stimulation of the bone walls and their retentive characteristics. **Conclusion:** These results suggest that Bond Apatite effectively promotes bone regeneration, offering a simplified and rapid approach to challenging bone defect cases.

Subject Areas

Dentistry

Keywords

Lateral Bone Defect, Biphasic Calcium Sulphate, Radiographic Observations

1. Introduction

Insufficient bone can pose an obstacle to implant treatment and is sometimes a contraindication. The most common clinical situation encountered in cases of bone insufficiency is lateral or horizontal bone insufficiency [1]. Several techniques exist for augmenting the lateral bone crest, with guided bone regeneration currently being the most widely discussed and used technique [2]. In 2010, a bone filling material consisting of a combination of biphasic calcium sulphate and hydroxyapatite was introduced: Bond Apatite. This material can be used in guided bone regeneration without the aid of a membrane, which simplifies its application [3]. This study aimed to observe the results of lateral bone augmentation using Bond Apatite and cone beam computed tomography (CBCT).

2. Patients and Methods

This was a descriptive observational study involving two adult patients with type 2 diabetes mellitus and clinical indications for lateral bone augmentation.

2.1. Inclusion and Exclusion Criteria

Inclusion criteria were controlled type 2 diabetes, the presence of lateral bone defects requiring augmentation, and the ability to attend follow-up appointments. Exclusion criteria included uncontrolled diabetes (HbA1c > 8.5%), systemic diseases affecting bone metabolism, smoking, pregnancy, or recent periodontal therapy. Only two patients were selected to provide a detailed pilot exploration of GBR in a high-risk population (diabetics), where healing outcomes can be variable and underreported.

2.2. CBCT Imaging and Measurement Protocol

All CBCT scans were acquired using a CS 3D Imaging v3.8.7 scanner at 90 kVp, 3.2 Ma 15 s, voxel size of 150 $\mu\text{m} \times 150 \mu\text{m} \times 150 \mu\text{m}$, and a field of view of 8 \times 8 cm. Linear and angular measurements were performed using DICOM-compatible software with an internal calibration tool. Each measurement was repeated twice by the same observer at two different time points, one week apart. Intra-observer reliability was calculated using the intraclass correlation coefficient (ICC), yielding a value of 0.92, indicating excellent consistency.

2.3. Bone Density Assessment

Bone density was assessed visually using grayscale analysis of CBCT images rather than quantitative Hounsfield units, which are not standardized in CBCT systems. Radiographic evaluations were conducted independently by two calibrated observers. Inter-observer agreement was evaluated using Cohen's kappa coefficient and demonstrated good agreement ($\kappa = 0.82$).

2.4. Patient 1

The first patient is a 63-year-old woman who has had diabetes for six years. Her

glycaemia was controlled using oral antidiabetic drugs, particularly metformin (800 mg) and glimepiride (3 mg). Patient 1's most recent HbA1c was 6.6%, indicating acceptable glycaemic control at the time of surgery. She was edentulous at tooth 21. A CBCT image showed a coronal ridge bone thickness of $2.3 \text{ mm} \pm 1.1 \text{ mm}$ (see **Figure 1**). A drug protocol was instituted pre- and post-operatively. Pre-operatively, she took amoxicillin 500 mg every eight hours for five days, starting the day before surgery, as well as prednisolone 20 mg for three days. Postoperatively, paracetamol 1000 mg was prescribed for pain relief. Local anaesthesia was administered using 4% articaine hydrochloride and 1:100,000 epinephrine. After creating a small, full-thickness flap extending 2 mm beyond the mucogingival line to visualise the bone defect, the bone was curetted to induce bleeding, after which biphasic calcium sulphate was injected. This hardened in the presence of blood and saliva when a dry compress was applied and adhered to the bone. The flap was then sutured.

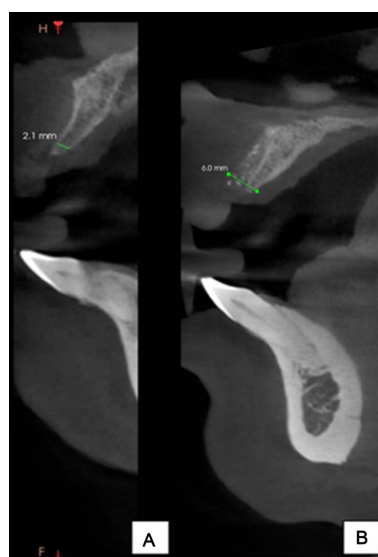


Figure 1. X-ray images showing the bone thickness of Patient 1 before and after guided bone regeneration. (a) Shows an orthogonal section of the bone thickness before guided bone regeneration. (b) Shows an orthogonal section of the bone thickness three months after guided bone regeneration.

2.5. Patient 2

The second patient was a 62-year-old woman who had been diagnosed with diabetes four years earlier. She was taking metformin (1000 mg) and gliclazide (60 mg). Her most recent HbA1c result was 6.8%, indicating that her blood glucose levels were under good control at the time of surgery. She presented with terminal periodontal lysis around tooth 11, which was connected to teeth 12, 13 and 21 via a metal retention wire. A CBCT X-ray revealed that the vestibular bone wall around the root of tooth 11 was almost absent, with a palatal wall measuring $0.95 \text{ mm} \pm 0.5 \text{ mm}$ in thickness at the apical third (see **Figure 2**). The same drug pro-

protocol was applied as for the first patient. After lifting the vestibular flap and cutting the retention suture, biphasic calcium sulphate was applied using the same procedure.

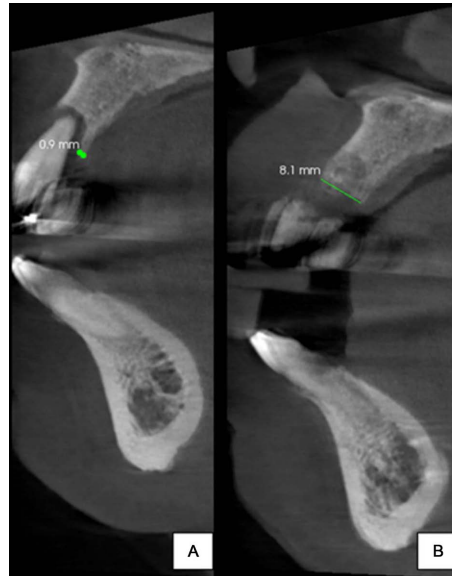


Figure 2. X-ray images showing the bone thickness of Patient 2 before and after guided bone regeneration. (a) Shows an orthogonal section of the bone thickness before guided bone regeneration. (b) Shows an orthogonal section of the bone thickness seven months after guided bone regeneration.

2.6. Radiographic Controle

The first patient underwent a radiographic check-up after 3 months and the second patient after 7 months due to travel.

3. Ethical Approval and Informed Consent

The study received ethical clearance from the Institutional Review Board of the Military Hospital Center of Niamey, Niger. Written informed consent was obtained from all participants prior to their inclusion in the study.

4. Results

4.1. Shape of Bone Defects

The first patient presented with a concave bone defect. The angles were measured at $154.5^\circ \pm 5.5^\circ$ between the mesial and palatal walls, and at $140.5^\circ \pm 7.5^\circ$ between the distal and palatal walls. This defect had four bone walls (see **Figure 3**). The second patient had a deeper, funnel-shaped defect with narrower angles ($118^\circ \pm 11^\circ$ and $125^\circ \pm 7^\circ$) and five bone walls (see **Figure 4**).

4.2. Contour of Regenerated Bone

Three months later, a transverse section of the first patient's jawbone showed a

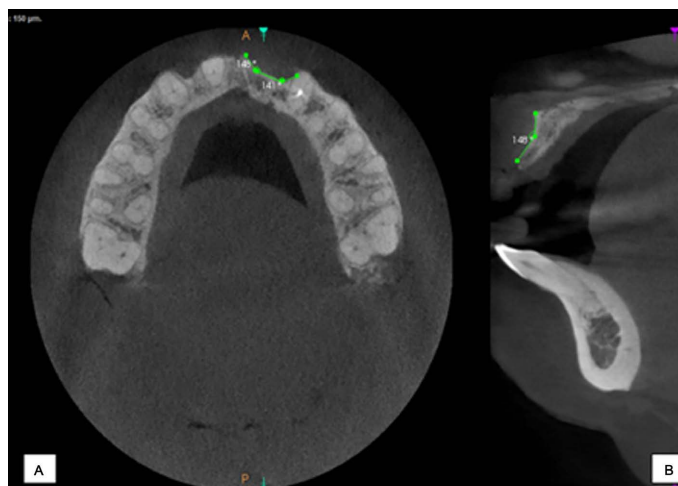


Figure 3. The shape of the bone defect in Patient 1. (a) Cross-section showing the proximal palatal angles of the bone defect in Patient 1. (b) shows an orthogonal section illustrating the palato-apical angle of the bone defect.

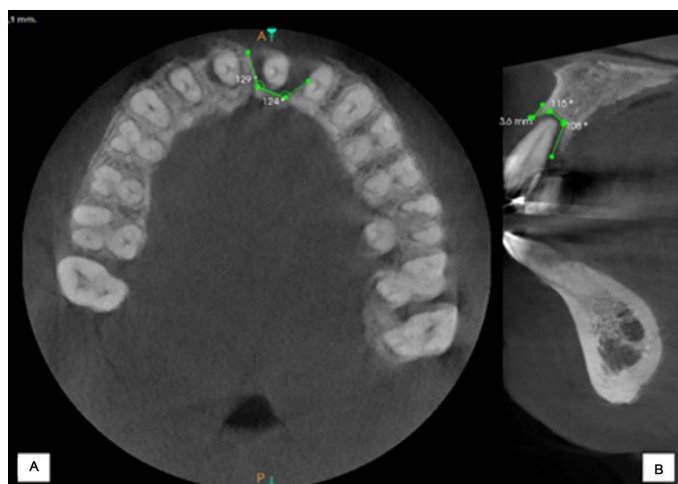


Figure 4. Bone defect shape in Patient 2. (a) Cross-section showing the proximal-palatal angles of the bone defect in Patient 2. (b) shows an orthogonal section of the bone defect in Patient 2, displaying the palatal-apical and apical-buccal angles.

clearly distinct new bone layer with a continuous vestibular margin and no invaginations (**Figure 5(a)**). After seven months, the second patient also displayed a newly formed bone layer with a continuous vestibular margin and no invaginations (see **Figure 5(b)**). In both cases, the new bone layer was clearly distinguishable from the host bone, being separated from it by the outer cortex (see **Figure 5**).

4.3. Density of Regenerated Bone

In the first patient, the radiographic density of the new layer was lower than that of the host medullary bone, containing non-resorbed hydroxyapatite particles (see

Figure 5(a)). By contrast, after seven months, the density of the new layer in the second patient had increased to a level close to that of the host medullary bone, with fewer hydroxyapatite particles present (**Figure 5(b)**).

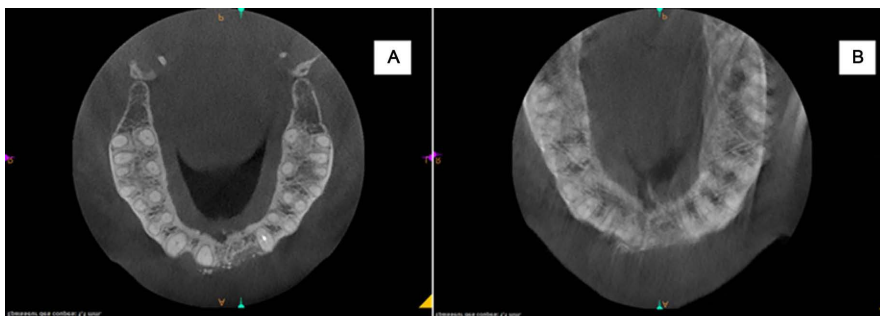


Figure 5. Cross sections showing the bone augmentation achieved in the two patients. (a) Illustrates the bone growth obtained after three months in Patient 1. (b) Cross section showing the bone growth achieved after seven months in Patient 2.

4.4. Variation in the Amount of Bone Regenerated

For the first patient, the initial bone thickness at the coronal margin of the crest was measured at $2.3 \text{ mm} \pm 1.1 \text{ mm}$. This increased to $6.3 \text{ mm} \pm 1.1 \text{ mm}$ following regeneration (see **Figure 1**). For the second patient, the initial thickness was $0.95 \text{ mm} \pm 0.5 \text{ mm}$, increasing to $8.0 \text{ mm} \pm 0.6 \text{ mm}$ after seven months — an increase of 7.05 mm (see **Figure 2**).

4.5. Bone Formation beyond the Limits of the Bone Defect

Analysis of cross-sectional and orthogonal sections indicates that both patients have an excess of regenerated bone beyond the limits of the proximal wall.

In the first patient, this excess extended $2 \text{ mm} \pm 0.8 \text{ mm}$ beyond the mesial wall and $3.25 \text{ mm} \pm 1.55 \text{ mm}$ beyond the distal wall on the vestibular side. The orthogonal reconstruction further confirms that the vestibular bone regeneration exceeds the expected continuity of the regenerated bone crest.

In the second patient, the excess bone was smaller, measuring $0.7 \text{ mm} \pm 0.6 \text{ mm}$ beyond the mesial wall and $1.6 \text{ mm} \pm 0.6 \text{ mm}$ beyond the distal wall, but was still present.

5. Discussion

5.1. Influence of Glycaemic Control on Healing

Although diabetes is associated with delayed wound healing and impaired bone regeneration, both patients in this the study demonstrated satisfactory outcomes. This could be attributed to their controlled glycaemic status, as evidenced by HbA1c levels below 7.5%, which are generally considered acceptable for surgical interventions. The literature suggests that well-controlled diabetes may not significantly compromise GBR outcomes compared to non-diabetic individuals [4]. These findings are consistent with those of Chackartchi *et al.* (2023), who reported

favourable GBR outcomes when using biphasic calcium sulfate without membrane coverage [5]. Furthermore, a multicentre study conducted in 2024 by Zhang *et al.* emphasised that, with proper case selection and glycaemic control, diabetic patients can achieve comparable outcomes to non-diabetics in bone regeneration procedures [6].

5.2. Radiographic Control Time

We opted for a timeframe of three months because the manufacturer recommends waiting three to four months after using Bond Apatite before placing the implant [7]. This is a significant advantage compared to other filling materials, for which a timeframe of six months is typically required. This aligns with the findings of Baranes *et al.* (2022) [7], who propose that the main component of Bond Apatite, calcium sulphate, is rapidly resorbed, facilitating rapid bone regeneration.

5.3. Regenerated Bone Contour

In both patients, new bone layers were formed with distinct, continuous vestibular margins and no invaginations. These results are consistent with those of Torrejón-Moya *et al.* (2022), who demonstrated that Bond Apatite prevents graft collapse and acts as a barrier to the infiltration of epithelial and connective cells [8]. Furthermore, Baranes *et al.* (2022) describe a similar process whereby a bone layer forms and attaches to the host bone without integrating with the filling material [9], a finding that was confirmed in our study.

5.4. Density of Regenerated Bone

Patient 1 exhibited lower-density bone formation with non-resorbed hydroxyapatite particles, whereas Patient 2 exhibited a density closer to that of the host medullary bone and fewer hydroxyapatite particles. According to Baranes *et al.* (2022) [7], Bond Apatite is composed of 66% calcium sulphate and 33% hydroxyapatite. Calcium sulphate is rapidly resorbed and becomes radiolucent after two to three weeks. However, it becomes radiopaque again after 12 weeks, and with the calcification of the osteoid matrix, the newly formed bone increases in radiopacity. Hydroxyapatite particles are not rapidly resorbed. Small and medium-sized particles are resorbed after three to six months. However, large hydroxyapatite particles, accounting for 10% of the total, are retained for a longer period [7].

5.5. Variation in Bone Thickness and Analysis of Defect Shapes

The difference in the increase in bone thickness (4 mm for Patient 1 and 7 mm for Patient 2) can be explained by the morphology of the bone defects. Patient 2 had a deeper bone defect with narrower angles. Therefore, this defect was more retentive than the bone defect in Patient 1. Nibali *et al.* (2021) [10] made this observation in their systematic review. They explain this finding by stating that deep lateral bone defects with narrower angles are more effective at retaining the blood clot necessary for bone regeneration. The Bond Apatite guided bone regeneration

technique indeed recommends stimulating the bone walls until bleeding occurs. The amount of blood retained in the defect determines the amount of bone tissue regenerated. However, the greater the retentiveness of the bone defect, the greater the amount of material. Furthermore, the greater the stimulation of the bone walls, the greater the source of bone cells and the greater the bone regeneration [10]. The clinical corollary of this observation is a change in the analysis of bone augmentation in lateral defects. Therefore, in the case of a lateral bone defect, bone thickness is not the only clinical factor to consider when choosing the appropriate technique.

5.6. Bone Surplus beyond the Limits of the Bone Defect

The bone surpluses observed in our study, particularly in Patient 1, suggest that Bond Apatite promotes bone regeneration beyond the boundaries of the defect (See **Figure 6**). This aligns with the findings of Nibali *et al.* (2021), who reported a similar surplus of bone and attributed this to stimulation of the bone walls and retention of the blood clot [10]. Together, these processes promote bone formation. In our study, the variation in the amount of bone regenerated beyond the limits of the defect in different patients can be explained by how distinct the defect boundaries are. In Patient 1, these boundaries were less defined, resulting in greater stimulation of the bone walls. In contrast, the second patient's defect had more clearly defined boundaries, confining the stimulation to precise areas of the defect. These findings suggest that creating more retentive defects with well-defined bone walls could be advantageous in cases of lateral bone regeneration involving poorly retentive defects. This approach would stimulate both the targeted area and the surrounding bone, resulting in a greater quantity of regenerated bone.

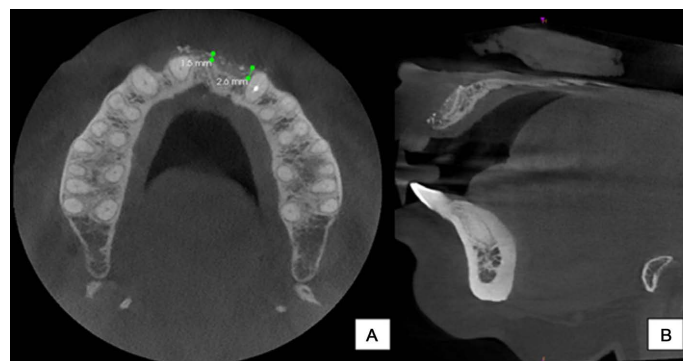


Figure 6. This figure demonstrates bone regeneration extending beyond the boundaries of the bone defect in Patient 1. (a) Cross-section showing bone regeneration extending beyond the boundaries of the bone defect in Patient 1. (b). An orthogonal section displaying bone regeneration extending beyond the boundaries of the bone defect in Patient 1.

6. Conclusion

Although the extent of bone regeneration varies depending on the morphology of

the bone defect, Bond Apatite enables effective regeneration. Furthermore, bone formation extending beyond the boundaries of the defect indicates that Bond Apatite facilitates broader regeneration than anticipated. These results offer new perspectives on the treatment of bone defects, providing better management of challenging clinical situations and simplifying surgical protocols. However, further research is needed to better understand the impact of this regeneration beyond the limits of the defect, and to optimise implant treatments.

Conflicts of Interest

The authors declare no conflicts of interest.

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