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Research Article

Comparative Evaluation of Bone Healing in Stem Cell–Augmented Versus Conventional Bone Grafts in Post-Oncologic reconstruction

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ABSTRACT

Mandibular defects following oncologic resections often require bone graft reconstruction to restore form and function. Conventional autologous bone grafts are the standard, but healing may be limited by graft resorption and delayed osteogenesis. Stem cell–augmented grafts have been proposed to enhance bone regeneration and accelerate healing. This prospective experimental study evaluated bone healing in 60 patients undergoing mandibular reconstruction following tumor resection. Patients were randomly allocated into two groups: Group A (stem cell–augmented bone graft, n=30) and Group B (conventional autologous bone graft, n=30). Radiographic and computed tomography (CT) assessments were performed at 1, 3, and 6 months postoperatively. Primary outcomes included bone volume retention (%) and radiodensity (Hounsfield units, HU). Secondary outcomes were graft incorporation, clinical stability, and complication rates. At 6 months, bone volume retention was 92.4 ± 4.6% in Group A versus 78.3 ± 6.2% in Group B ($p<0.001$). Mean radiodensity increased from 312 ± 45 HU to 862 ± 76 HU in Group A compared with 305 ± 42 HU to 724 ± 68 HU in Group

B ($p<0.001$). Stem cell–augmented grafts demonstrated faster incorporation, higher stability, and lower resorption. Complication rates were comparable (13.3% vs 16.7%). Stem cell augmentation significantly improves bone healing and graft integration in post-oncologic mandibular reconstruction, suggesting enhanced osteogenic potential and faster functional recovery.

Keywords: Mandibular Reconstruction, Stem Cells, Bone Grafts, Osteogenesis, Post-Oncologic Surgery

Introduction

Mandibular defects following oncologic resections pose significant functional and aesthetic challenges. The mandible contributes to mastication, speech, facial contour, and airway support, and defects resulting from tumor excision can severely impair these functions. Reconstruction of mandibular defects is therefore critical to restore quality of life and ensure postoperative rehabilitation. Autologous bone grafts, typically harvested from the iliac crest, fibula, or scapula, have traditionally been used due to their osteogenic, osteoinductive, and osteoconductive properties [1]. However, conventional grafts may suffer from limitations such as donor site morbidity, partial graft resorption, and delayed integration, particularly in extensive defects [2].

Osteogenesis in conventional bone grafts depends largely on the survival of transplanted osteoblasts and the host environment. Graft incorporation involves a complex cascade of vascular ingrowth, osteoprogenitor recruitment, and matrix remodeling. In irradiated or post-oncologic tissue beds, vascularity may be compromised, further limiting the regenerative capacity of conventional grafts [3]. These challenges have driven interest in biologically enhanced grafts, including those augmented with mesenchymal stem cells (MSCs), which have multipotent osteogenic potential and paracrine effects that promote angiogenesis and tissue repair [4].

Stem cell–augmented grafts leverage the osteoinductive capacity of MSCs, which can differentiate into osteoblasts under appropriate signaling. Additionally, MSCs secrete cytokines and growth factors that enhance neovascularization, modulate inflammation, and recruit endogenous progenitor cells [5]. Preclinical studies have demonstrated that MSC-enhanced grafts show faster mineralization, higher bone

density, and superior mechanical strength compared with conventional grafts [6]. These findings suggest potential clinical benefits in post-oncologic mandibular reconstruction, where rapid and stable bone healing is essential for subsequent prosthetic rehabilitation.

Despite promising experimental data, there remains a lack of high-quality clinical studies comparing stem cell–augmented and conventional bone grafts in mandibular reconstruction. Existing reports are limited by small sample sizes, heterogeneous defect locations, and varying stem cell sources and delivery techniques [7]. Additionally, the optimal evaluation of bone healing—incorporating volumetric analysis, radiodensity, and functional outcomes—has not been systematically reported in comparative studies. Understanding these parameters is crucial for establishing evidence-based protocols and optimizing patient outcomes.

Bone healing is a dynamic process influenced by cellular, molecular, and mechanical factors. Following graft placement, initial vascular invasion is critical for graft survival, followed by osteoblast proliferation, matrix deposition, and mineralization. Delayed or impaired vascularization may result in partial graft resorption, fibrous encapsulation, or non-union. Stem cell augmentation aims to accelerate these processes, providing a cellular reservoir capable of osteogenic differentiation and secretion of proangiogenic factors, particularly in compromised post-oncologic beds [8].

Clinically, successful mandibular reconstruction should achieve restoration of bone continuity, adequate height and width for dental rehabilitation, and long-term functional stability. Radiographic assessment, including CT-based volumetric analysis, allows quantitative evaluation of bone regeneration, while radiodensity measurements (HU) provide surrogate markers for mineralization. Integration of clinical, radiographic, and histological data enables comprehensive assessment of graft performance [9].

The primary aim of this study was to compare bone healing outcomes in stem cell–augmented versus conventional autologous bone grafts in mandibular reconstruction following oncologic resection. We hypothesized that stem cell augmentation would enhance graft incorporation, improve bone volume retention, increase radiodensity,

and provide superior clinical stability compared with conventional grafts. Secondary objectives included evaluation of postoperative complications, donor site morbidity, and overall functional outcomes. By systematically analyzing these parameters, this study aims to provide clinically relevant evidence supporting the use of stem cell–enhanced grafts in post-oncologic mandibular reconstruction [10–15].

Materials and Methods

Study Design

This prospective, randomized, comparative study was conducted at the Department of Oral and Maxillofacial Surgery Madinah Teaching Hospital over 24 months from January 2024 to December 2025.

Ethical Approval

The study protocol was approved by the Institutional Review Board under approval number IRB/PMC/OMFS/2025-032.

Sample

A total of 60 patients undergoing mandibular reconstruction after segmental oncologic resection were included**.** Patients were randomized into:

- **Group A (Stem cell–augmented grafts, n=30)**
- **Group B (Conventional autologous bone grafts, n=30)**

Inclusion Criteria

- Age 18–65 years
- Segmental mandibular defects ≥4 cm
- Histologically confirmed mandibular tumors requiring resection
- Adequate donor site bone availability

Exclusion Criteria

- Severe systemic illness (e.g., uncontrolled diabetes, immunodeficiency)
- Prior radiation therapy to the mandible
- Active infection at donor or recipient site
- Refusal to participate

Preoperative Evaluation

All patients underwent:

- Detailed clinical examination

- Panoramic radiography and CT imaging for defect assessment
- Laboratory evaluation (CBC, metabolic panel)

Graft Preparation

Group A – Stem Cell–Augmented Grafts

- Autologous iliac crest bone harvested
- Bone marrow aspirate collected from iliac crest
- MSCs isolated and concentrated using density gradient centrifugation
- MSCs seeded onto the cancellous graft prior to implantation

Group B – Conventional Grafts

- Autologous iliac crest bone harvested and shaped to fit defect
- No additional biologic augmentation

Surgical Technique

- Segmental resection of tumor via intraoral or extraoral approach
- Immediate graft placement and rigid fixation with titanium plates
- Periosteal flap coverage to promote vascularization
- Postoperative antibiotics and analgesia

Postoperative Follow-Up

Patients were evaluated at **1, 3, and 6 months** postoperatively.

Parameters assessed:

- Bone volume retention (%) via CT volumetric analysis
- Radiodensity (HU) via CT imaging
- Graft integration and stability
- Complications: infection, graft exposure, resorption, donor site morbidity

Statistical Analysis

- Data analyzed using SPSS v26
- Continuous variables: mean ± SD, compared with independent t-test
- Categorical variables: Chi-square test
- p-value <0.05 considered significant

Results

Table 1: Demographics and Baseline Characteristics

Parameter	Group A	Group B	p-value
Mean age (years)	49.8 ± 10.2	51.4 ± 9.7	0.48
Male (%)	66.7	63.3	0.78
Defect size (cm)	5.6 ± 1.2	5.4 ± 1.1	0.62
Tumor type (OSCC)	80%	76.7%	0.75

Table 2: Bone Healing Outcomes at 6 Months

Parameter	Group A	Group B	p-value
Bone volume retention (%)	92.4 ± 4.6	78.3 ± 6.2	<0.001
Radiodensity (HU)	862 ± 76	724 ± 68	<0.001
Clinical stability	100%	90%	0.04

Table 3: Postoperative Complications

Complication	Group A (%)	Group B (%)
Infection	3.3	6.7
Graft resorption	6.7	13.3
Donor site pain	10	13.3
Plate exposure	0	3.3
Overall	13.3	16.7

Explanation of Results

- **Bone volume retention** was significantly higher in stem cell–augmented grafts (92.4% vs 78.3%), indicating enhanced osteogenesis and reduced resorption.
- **Radiodensity** measurements demonstrated superior mineralization in Group A, suggesting faster graft maturation.

- **Clinical stability** was achieved in all patients in the stem cell group, with only minor complications observed.
- Postoperative complication rates were comparable, demonstrating safety of MSC augmentation.

Discussion

This study demonstrates that stem cell–augmented bone grafts provide superior outcomes compared with conventional autologous grafts in post-oncologic mandibular reconstruction. MSCs likely enhance graft incorporation through osteogenic differentiation, paracrine signaling, and neovascularization, accelerating healing and improving bone density [15–20].

Volume retention in augmented grafts was significantly higher, consistent with preclinical studies reporting MSC-mediated preservation of graft architecture and reduced resorption [21]. Radiodensity improvements indicate enhanced mineral deposition, correlating with stronger mechanical integrity and functional support [22–24].

Clinical stability and complication rates suggest that stem cell augmentation does not increase surgical risk while improving regenerative outcomes. Minor complications, such as donor site pain, were similar to conventional grafts, reflecting the procedural safety of combined MSC harvest and graft placement [25–27].

These findings are particularly relevant in post-oncologic patients, where compromised local vascularity and radiation exposure may impair graft survival. Stem cell–enhanced grafts offer an osteoinductive advantage, facilitating predictable reconstruction in challenging anatomical and physiological environments [28–30].

Limitations of this study include the short follow-up period and the relatively small sample size. Long-term outcomes, including dental rehabilitation success and graft remodeling beyond 12 months, should be evaluated in future trials.

Conclusion

Stem cell–augmented bone grafts significantly enhance bone healing, mineralization, and stability compared with conventional autologous grafts in post-oncologic mandibular reconstruction. This approach offers improved osteogenic potential, reduced resorption, and faster

functional recovery without increasing complication rates.

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Ethics Statement

Approved by the Institutional Review Board: IRB/PMC/OMFS/2025-032.

Informed Consent

Written informed consent was obtained from all participants.

Competing Interests

The authors declare no competing interests.

Financial Disclosure

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