

Clinical and Radiographic Outcomes of Second Molars with External Root Resorption Following Impacted Third Molar Removal: A Retrospective CBCT-Based Cohort Study

Baocheng Yao

Peking University Third Hospital

Shiyu Qiu

Peking University Third Hospital

Chengyi Wang

Peking University Third Hospital

Qiao Ling

Peking University Third Hospital

Ning Ma

kqmn@sina.com

Peking University Third Hospital

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Abstract

Objective

To evaluate the clinical and radiographic outcomes of second molars (M2) affected by external root resorption (ERR) following impacted third molar (M3) removal, and to assess the influence of adjunctive guided bone regeneration (GBR).

Methods

This retrospective cohort study included patients presenting with ERR of M2s associated with impacted M3s who underwent M3 extraction with or without concurrent GBR. Cone-beam computed tomography (CBCT) was used to assess ERR progression and distal alveolar bone levels before surgery and at least 6 months postoperatively. Pulp sensibility was also evaluated. Changes in distal bone height were compared between groups. Generalized estimating equations were used to evaluate the association between treatment modality and bone gain while adjusting for baseline defect severity and potential confounders. Interaction analysis was performed to assess whether the effect of GBR varied according to baseline defect severity.

Results

ERR progression ceased in all cases following removal of the impacted M3s, and pulp sensibility was maintained in all teeth without preoperative endodontic treatment. Distal bone gain was significantly greater in the GBR group compared with extraction alone (6.32 ± 2.67 mm vs. 4.08 ± 3.50 mm; $P = 0.007$). After adjustment, GBR remained significantly associated with increased bone gain ($\beta = 1.202$, $P = 0.004$). No significant interaction between treatment modality and baseline defect severity was observed ($P = 0.945$).

Conclusion

The removal of the impacted third molar is sufficient to arrest ERR. Prophylactic root canal treatment is clinically unwarranted as pulp sensibility is robustly maintained. However, spontaneous periodontal recovery of ERR-associated distal defects appeared incomplete. Adjunctive GBR was associated with enhanced distal bone regeneration.

Clinical Relevance

External root resorption of second molars associated with impacted third molars may stabilize following extraction of third molars, with preservation of pulp sensibility. However, residual distal periodontal defects frequently persist. Adjunctive guided bone regeneration may improve periodontal healing and enhance distal bone regeneration in affected second molars.

Introduction

The clinical magnitude of external root resorption (ERR) associated with impacted third molars (M3) has long been obscured by the limitations of conventional radiographic imaging. Historically, the prevalence

of ERR was considered negligible, often cited 0.3–13.3% in studies relying on panoramic radiography[1–4]. However, this low incidence appears to be a diagnostic artifact caused by the limitations of 2D imaging. Recent three-dimensional analysis using Cone-beam computed tomography (CBCT) reported incidence rates soaring to 11.0-54.3%[5–9]. This dramatic diagnostic shift underscores that ERR is a widespread, yet frequently underestimated, threat to second molars (M2s).

Removal of the impacted M3 leads to arrest of the resorptive process and preservation of pulp vitality of M2s. Although Anbu and Song favor prophylactic RCT of M2s with ERR[10, 11], Qu et al. advocate extracting only the M3 and 89% (56/63) M2 remains asymptomatic and normal response to heat and cold tests, proving that only extraction of M3 is enough for M2 pulp vitality[12].

The periodontal consequences of M2 with ERR remains insufficiently investigated. ERR is accompanied by distal alveolar bone loss, resulting in a combined defect involving both root structure and periodontal support. The extent to which such defects can undergo spontaneous healing following M3 removal remains insufficiently investigated. Guided bone regeneration (GBR) has been widely used to enhance periodontal bone regeneration, particularly in vertical and contained defects. In the context of M3 surgery, several studies have suggested that GBR may improve distal bone healing of M2s[13–18]. However, existing evidence has largely focused on cases without concomitant root resorption, and it remains unclear whether the presence of ERR alters the regenerative potential or the effectiveness of GBR.

Therefore, the aim of the present study was to evaluate the periodontal healing outcomes of M2s affected by ERR following impacted M3 removal, and to investigate the potential adjunctive benefit of GBR. In addition, the study explored whether the effect of GBR was influenced by baseline defect severity.

Materials & Methods

Study Design

This single-centre retrospective study was conducted and reported in accordance with the STROBE statement guidelines for cohort studies. The protocol was approved by the Ethics Committee of Peking University Third Hospital (Approval No. IRB00006761-M2024038) and conducted in accordance with the Declaration of Helsinki.

Study Population

Patients diagnosed with ERR of M2 associated with impacted M3 between 2022–2024 were screened. Inclusion criteria were:

(1) ERR was defined radiographically as "a clear loss of substance in the root of the adjacent M2 due to direct contact with an impacted third molar" adapted from Al-Khateeb and Bataineh[4] (Figure 1a).

- (2) Clinically asymptomatic M2 with normal pulp sensibility. This was strictly defined as a positive response to cold testing (using Endo-Ice) comparable to control teeth, with no lingering pain, and absence of tenderness to percussion or palpation.
- (3) Extraction of the aetiological M3 performed after the ERR diagnosis.
- (4) A minimum observation period of 6 months.
- (5) Availability of high-quality CBCT scans (voxel size ≤ 0.2 mm) pre-operatively and at the final follow-up.

Exclusion criteria included:

- (1) Presence of caries in the resorption area, or apical periodontitis, sinus tract, or mobility $\geq$ Grade II prior to intervention (Figure 1b, c).
- (2) Resorption extending to the pulp chamber floor (Figure 1d).
- (3) ERR attributed to other aetiologies (e.g., cysts, tumours, or trauma).
- (4) History of or active orthodontic treatment.
- (5) Image artifacts (e.g., beam hardening from metal restorations) preventing precise measurement.

Sample Size and Grouping

As this was a retrospective study involving consecutive sampling of all eligible cases within the defined period, an a priori sample size calculation was not performed. Patients were stratified into two groups based on the surgical intervention received: the Extraction-Only Group (M3 extraction alone) and the GBR Group (M3 extraction with concurrent GBR).

Treatment allocation was not randomized. GBR was more likely to be recommended in cases presenting with one or more of the following conditions: (1) suspected pulpal involvement, (2) radiographic evidence of root length alteration, or (3) a relatively deep distal bone defect (approximately >8 mm). Final treatment decisions were made jointly by the clinician and patient.

Radiographic Assessment

CBCT images were acquired using 3D eXam, KaVo, Warthausen, Germany (parameters: 120 kV, 5 mA, FOV 16 cm $\times$ 8 cm, voxel size 0.2 mm) and Smart3D, LargeV, Beijing, China (parameters: 100 kV, 6 mA, FOV 12 cm $\times$ 8 cm, voxel size 0.1 mm). Despite the use of different devices, image reconstruction and measurement protocols were standardized.

Five specific radiographic parameters were measured on these adjusted planes (Figure 2):

Root Length (r): The distance from the Cemento-Enamel Junction (CEJ) to the anatomical apex. If the apex was resorbed, measurement was taken to the resorbed tip (Figure 2c). If the CEJ was compromised, the upper margin of the ERR served as the reference (Figure 2e).

Upper Boundary Distance (u): The distance from the CEJ to the coronal margin of the ERR defect (Figure 2a). Recorded as 0 mm if the CEJ was involved.

Lower Boundary Distance (l): The distance from the apical margin of the ERR defect to the root apex (Figure 2a). Recorded as 0 mm if the apex was resorbed.

Distal Alveolar Bone Height (h): The distance from the distal CEJ to the distal alveolar bone crest (ABC) (Figure 2b). A smaller value of h indicates better bone level.

Comparison Root Length (c): The length of a homologous healthy root (e.g., the mesiobuccal root for an affected distobuccal root, or the root of the adjacent first molar if the M2 roots were compromised) (Figure 2c-d).

Based on these parameters, the Vertical Dimension of ERR (e) was calculated as:

$e=r-u-l$ (root length didn't change)

or

$e=c-r$ (root length changed)

All measurements were performed by two calibrated examiners. Intra- and inter-examiner reliability were assessed using intraclass correlation coefficients (ICC).

Surgical Procedures

All surgical procedures were performed by the same experienced oral surgeon. Following local anesthesia, a full-thickness mucoperiosteal flap was elevated to expose the distal aspect of the M2. The impacted M3 was removed using minimally invasive techniques.

In the GBR group, the extraction socket and distal defect were grafted with deproteinized bovine bone mineral (Bio-Oss, Geistlich, Switzerland), followed by coverage with a resorbable collagen membrane (Bio-Gide, Geistlich, Switzerland). Primary wound closure was achieved in all cases. (Figure 3)

Outcome Measures

The primary outcome was radiographic bone gain (Δh), defined as the change in distal bone height between baseline and follow-up. Δh was analyzed as a continuous variable assuming a normal distribution with an identity link function.

Secondary outcomes included cessation of ERR progression and pulp vitality status at follow-up.

Statistical Analysis

Statistical analyses were performed using SPSS software, version 29.0 (SPSS Inc., Chicago, IL, USA). Generalized estimating equations (GEE) with an exchangeable correlation structure were used to account for clustering of teeth within patients. Multivariable models were constructed to evaluate the association between treatment modality and bone gain, adjusting for potential confounders.

In the primary model, the association between treatment modality (GBR vs. Extraction-only) and Δh was evaluated after adjustment for baseline defect severity and potential confounders, including baseline distal bone height, defect ratio, age, and tooth position. The defect ratio was defined as the proportion of the resorptive defect relative to root length. In cases with root length alteration, relative change in root length compared with the contralateral tooth was used.

To assess potential collinearity, Pearson correlation analysis was performed between baseline distal bone height and defect ratio prior to model construction.

To explore whether the effect of GBR varied according to baseline defect severity, an interaction model was constructed. Baseline distal bone height was mean-centered to reduce collinearity, and an interaction term between treatment modality and centered baseline bone height was included in the model.

Regression coefficients (β) with robust standard errors were reported. A two-sided P value < 0.05 was considered statistically significant.

Results

Study population and baseline characteristics

A total of 233 cases were initially screened, of which 65 M2s in 55 patients met the inclusion criteria and were included in the final analysis (Fig. 4). To ensure statistical independence and avoid data clustering within a single tooth, only one root per tooth was included in the quantitative analysis.

Baseline demographic and radiographic characteristics are summarized in Table 1. No statistically significant differences were observed between the GBR group (n = 43) and the extraction-only group (n = 22) in terms of age, sex distribution, tooth position, or baseline radiographic parameters (all P > 0.05) except preoperative distal alveolar bone height, indicating comparability between groups.

Table 1
Demographic and Baseline Characteristics of the Study Population.

Variables	Total (n = 65)	GBR Group (n = 43)	Extraction-Only Group (n = 22)	P Value	Statistical test
Demographics					
Age (years), Mean $\pm$ SD	25.77 $\pm$ 4.4	26.28 $\pm$ 3.16	24.77 $\pm$ 3.10	0.091	Independent <i>t</i> -test
Gender (Male/Female), n	22/43	14/29	8/14	0.759	Chi-square test
Tooth Characteristics					
Tooth Position (Maxilla/Mandible), n	18/47	11/32	7/15	0.595	Chi-square test
Radiographic Measurements					
ERR Posititon (Cervical/Middle/Apical), n	3/43/19	2/28/13	1/15/6	0.968	Chi-square test
ERR Root Length (<i>r</i>), mm (Mean $\pm$ SD)	9.69 $\pm$ 2.81	9.53 $\pm$ 2.90	1.02 $\pm$ 2.07	0.814	Mann-Whitney <i>U</i> test
ERR Vertical Dimension (<i>e</i>), mm (Mean $\pm$ SD)	5.25 $\pm$ 1.41	5.19 $\pm$ 1.40	5.36 $\pm$ 1.47	0.658	Independent <i>t</i> -test
Distal Bone Height (<i>h</i>), mm (Mean $\pm$ SD)	7.82 $\pm$ 3.13	8.30 $\pm$ 2.59	6.88 $\pm$ 3.90	0.043	Mann-Whitney <i>U</i> test
ERR Severity					
Pulp Involvement (Yes/No), n	39/26	25/18	14/8	0.669	Chi-square test
Number of Affected Roots (1 / $\geq$ 2), n	63/2	42/1	21/1	0.624	Chi-square test
Root length change (Yes/No), n	19/46	13/30	6/16	0.804	Chi-square test

Reliability of radiographic measurements

Radiographic measurements demonstrated high reproducibility. The intra-examiner ICC was good to excellent (0.662–0.981 for measurer 1 and 0.877–0.984 for measurer 2), and the inter-examiner ICC was excellent (0.808–0.957).

Cessation of external root resorption and pulp sensibility

Following removal of the impacted M3s, ERR ceased in all included cases, with no radiographic evidence of further progression during the follow-up period.

Regarding pulpal status, excluding one tooth that had undergone preoperative root canal treatment, all remaining teeth (64/64, 100%) maintained positive pulp sensibility at the final follow-up, as assessed by cold testing. No signs of periapical pathology or increased tooth mobility were observed clinically or radiographically.

Periodontal healing outcomes

Concurrent GBR significantly improved distal periodontal outcomes compared to spontaneous healing (Fig. 5). Figure 5e visualizes the comparative recovery of Δh , which was 6.32 ± 2.67 mm in the GBR group and 4.08 ± 3.50 mm in the Extraction-Only group, with a statistically significant difference between groups ($P = 0.007$).

To account for potential confounding factors and clustering of teeth within patients, GEE analysis was performed. After adjustment for baseline defect severity and other covariates, treatment modality remained a significant predictor of distal bone gain, with GBR associated with greater bone gain compared with extraction alone ($\beta = 1.202$, $P = 0.004$). The magnitude of the observed difference suggests a clinically relevant improvement in distal bone reconstruction.

Baseline distal bone height was also significantly associated with Δh , indicating that sites with more severe initial bone loss exhibited greater absolute bone gain.

Collinearity and interaction analysis

Pearson correlation analysis showed no strong correlation between baseline distal bone height and defect ratio ($r = 0.137$), indicating that both variables could be included in the multivariable model without significant collinearity.

To explore whether the effect of GBR varied according to baseline defect severity, an interaction model was constructed. The interaction term between treatment modality and baseline distal bone height was not statistically significant ($P = 0.945$), suggesting that the effect of GBR on distal bone gain did not vary significantly across the range of baseline defect severities observed.

Discussion

ERR-associated defects differ from conventional distal periodontal defects following impacted M3 removal. Unlike plaque-driven periodontal breakdown, ERR is initiated by direct mechanical contact between adjacent teeth, resulting in concurrent root substance loss and localized alveolar bone remodeling[19, 20]. This combined involvement of the root surface and supporting bone may influence subsequent healing.

Removal of the causative M3 resulted in cessation of ERR in all cases, with maintained pulp sensibility as assessed by cold testing. These findings are consistent with previous reports and support a conservative approach, as endodontic intervention does not appear to be indicated in the absence of clinical signs of pulpal involvement[12].

Despite increasing recognition of ERR, its periodontal implications remain poorly characterized. Previous studies have focused primarily on the progression of resorption and pulpal outcomes, whereas distal periodontal healing has been investigated mainly in non-resorptive contexts[13, 17, 18, 21]. Whether these findings can be extrapolated to ERR-associated defects remains uncertain.

This gap may be partly explained by the relatively low prevalence of clinically significant ERR, particularly in advanced forms, which limits the feasibility of assembling sufficiently large cohorts. In addition, surgical management of ERR-associated impacted M3s is often more technically demanding. Close proximity and direct contact between teeth may increase the risk of iatrogenic damage to the already compromised M2, which may discourage routine inclusion of such cases in clinical studies, especially those involving regenerative procedures. Furthermore, ERR-associated defects do not conform to conventional periodontal defect models, as they involve both root surface loss and alveolar bone deficiency.

In the present cohort, distal bone defects of varying severity were consistently observed, indicating that resolution of the resorptive process does not equate to complete periodontal recovery. Compared with non-resorptive defects, the altered root surface morphology in ERR may provide a less favorable substrate for spontaneous periodontal reattachment. Resorption-related irregularities of the root surface may compromise clot stability and early wound organization, potentially limiting spontaneous bone fill following extraction alone.

GBR provide a space-maintaining scaffold that supports more predictable bone regeneration in compromised sites. The present results showed greater distal bone gain in the GBR group compared with extraction alone, and this association remained significant after adjustment for baseline defect severity and other covariates. No significant interaction between treatment modality and baseline defect height was detected, suggesting that the relative benefit of GBR was observed across the range of defect severities included. However, this finding should be interpreted with caution given the limited sample size and the possibility of insufficient statistical power to detect interaction effects.

This may support a lower threshold for considering adjunctive regenerative intervention in ERR-associated cases. Management of ERR-associated defects may require a different decision-making framework from that used in conventional M3 surgery. In addition to the extent of alveolar bone loss, the structural integrity and morphology of the affected root surface should be considered. Even after cessation of resorption, the altered root anatomy may reduce the predictability of spontaneous periodontal healing.

Several limitations should be acknowledged. The retrospective design introduces potential selection bias, particularly as treatment allocation was based on clinical judgment. Although statistical adjustment was performed, residual confounding cannot be excluded. In addition, clinical periodontal parameters, such as probing depth and clinical attachment level, were not available, and radiographic bone gain was used as a surrogate outcome. The sample size was relatively small, which may have limited statistical power, particularly for interaction analyses. The present study evaluated early radiographic healing at 6 months and cannot determine the long-term stability of the observed bone gain.

Within these limitations, the present findings indicate that removal of the etiological factor effectively arrests the resorptive process. Prophylactic root canal treatment is clinically unwarranted as pulp sensibility is robustly maintained, while adjunctive GBR appears to enhance distal bone regeneration.

Conclusion

The removal of the impacted third molar is sufficient to arrest ERR. Prophylactic root canal treatment is clinically unwarranted as pulp sensibility is robustly maintained. However, spontaneous periodontal recovery of ERR-associated distal defects appeared incomplete. Adjunctive GBR was associated with enhanced distal bone regeneration.

Declarations

Data availability

Data available upon reasonable request.

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Conflict of Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare no conflict of interest regarding the bone grafting materials used in this study.

Author information

Baocheng Yao and Shiyu Qiu contributed equally to this work and share first authorship.

Authors and Affiliations

Department of Stomatology, Peking University Third Hospital, 49 North Garden Rd, Haidian District
Beijing 100191, P.R.China

Baocheng Yao, Shiyu Qiu, Chengyi Wang, Qiao Ling & Ning Ma

Contributions

Baocheng Yao: Conceptualization (Lead); Methodology (Lead); Writing – Review & Editing (Lead). Shiyu Qiu: Data Curation (Lead); Formal Analysis (Lead); Writing – Original Draft (Lead). Chengyi Wang: Investigation (Equal). Qiao Ling: Investigation (Equal). Ning Ma: Supervision (Lead); Validation (Lead). All authors have read and agreed to the published version of the manuscript.

Corresponding author

Correspondence to Ning Ma.

Ethics declarations

Informed consent

All patients signed an informed consent at the moment of enrolment.

Research involving Human Participants and/or Animals

The retrospective evaluation was approved by the Ethics Committee of Peking University Third Hospital (Approval No. IRB00006761-M2024038).

Competing interests

The authors declare no competing interests.

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Figures

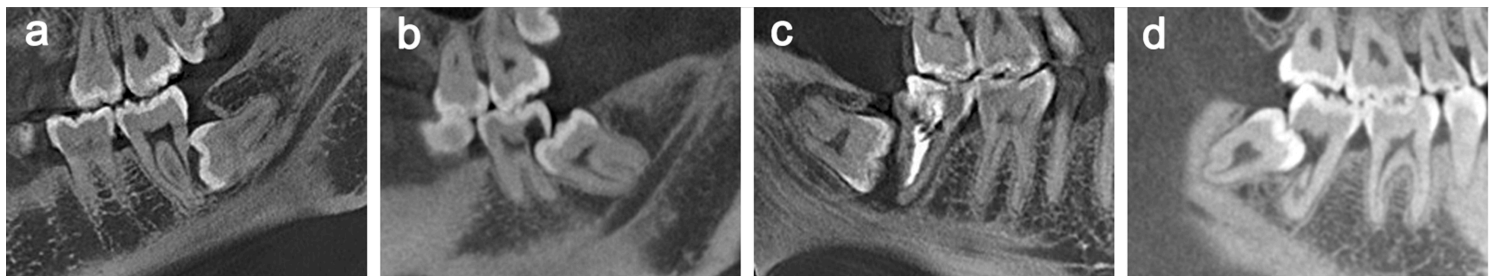


Figure 1

Radiographic criteria.

(a) Included case: sagittal CBCT view of a mandibular M2 with external root resorption associated with an impacted M3.

(b–d) Excluded cases showing caries within the resorptive defect (b), apical periodontitis (c), and resorption involving the pulp chamber floor (d).

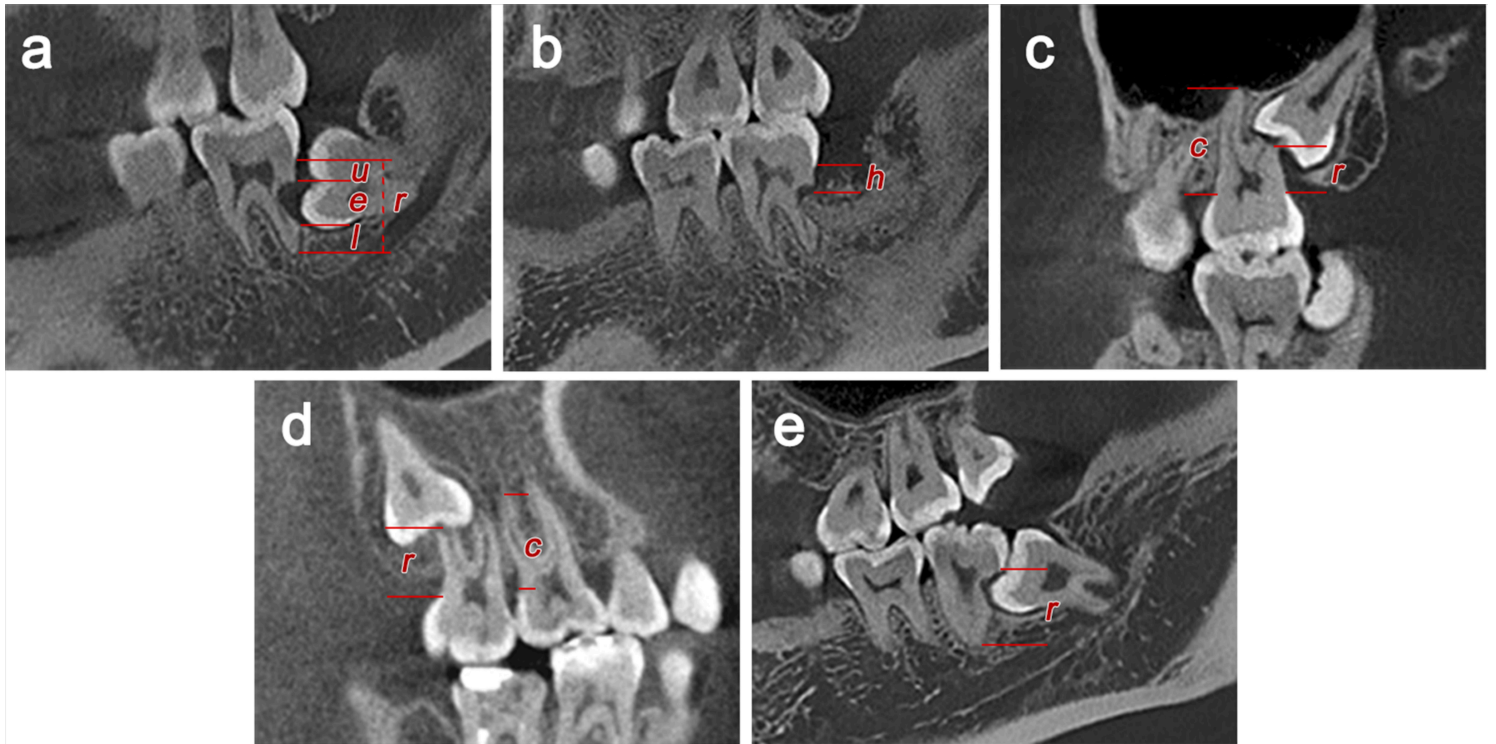


Figure 2

Schematic definition of radiographic indices.

(a) Defect dimensions: root length (r), distance from CEJ to upper margin (u), distance from lower margin to apex (l) and vertical dimension (e).

(b) Distal alveolar bone height (h): CEJ to alveolar crest.

(c–e) Reference standards: root length (r) and homologous root length (c) for cases with compromised CEJ or apex.

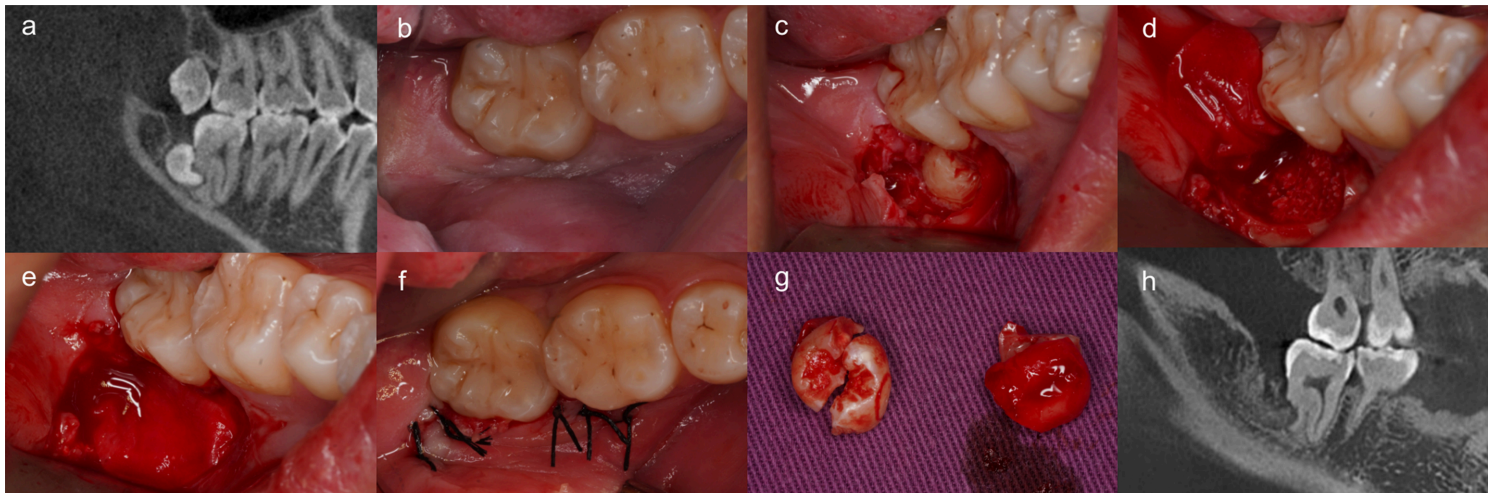


Figure 3

Surgical procedure for impacted M3 removal with guided bone regeneration.

(a) Preoperative CBCT assessment.

(b–f) Key surgical steps, including flap elevation, defect exposure, graft placement, and membrane coverage.

(g) Extracted impacted M3.

(h) Postoperative CBCT at follow-up.

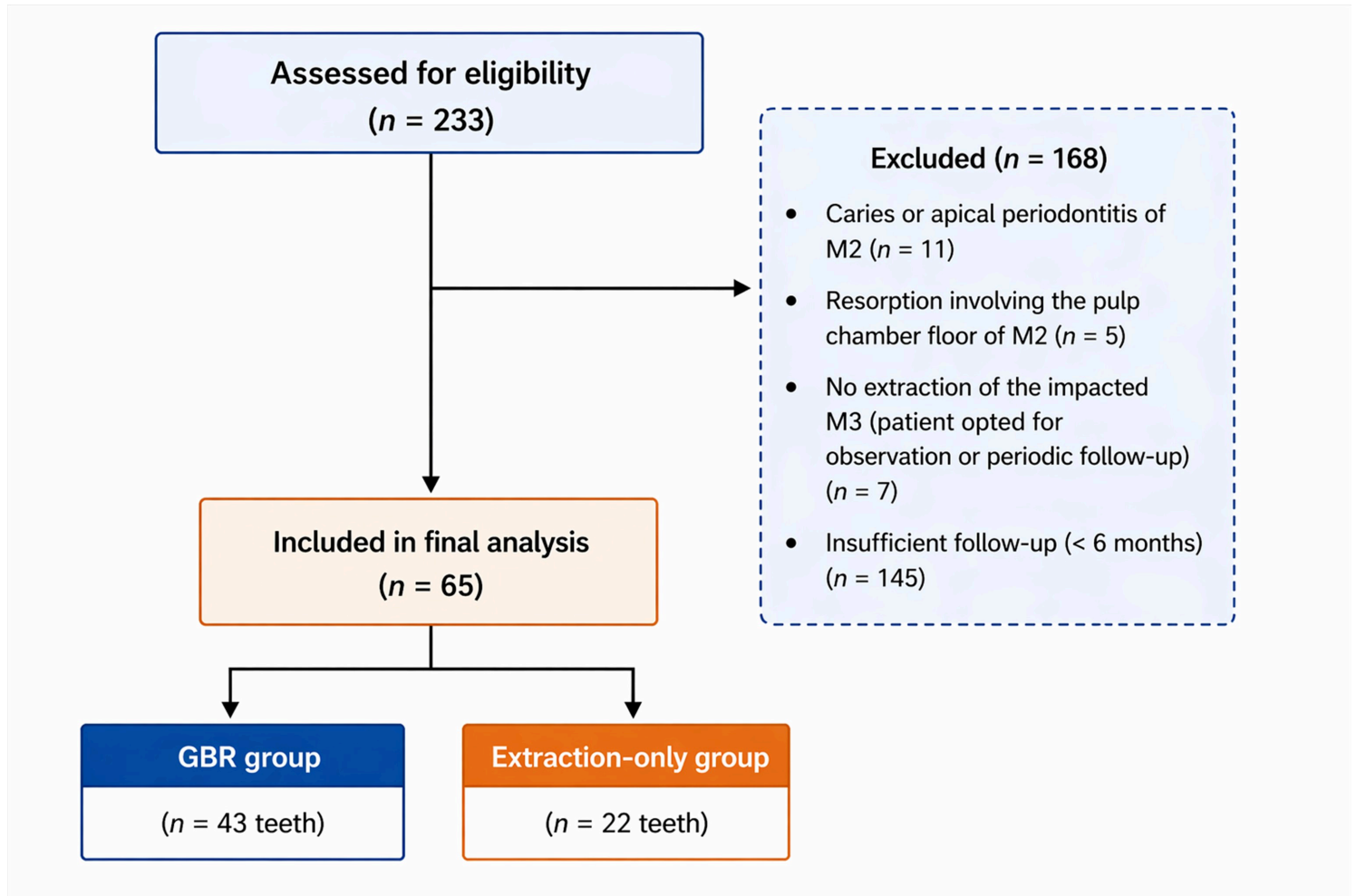


Figure 4

Flow-chart of study.

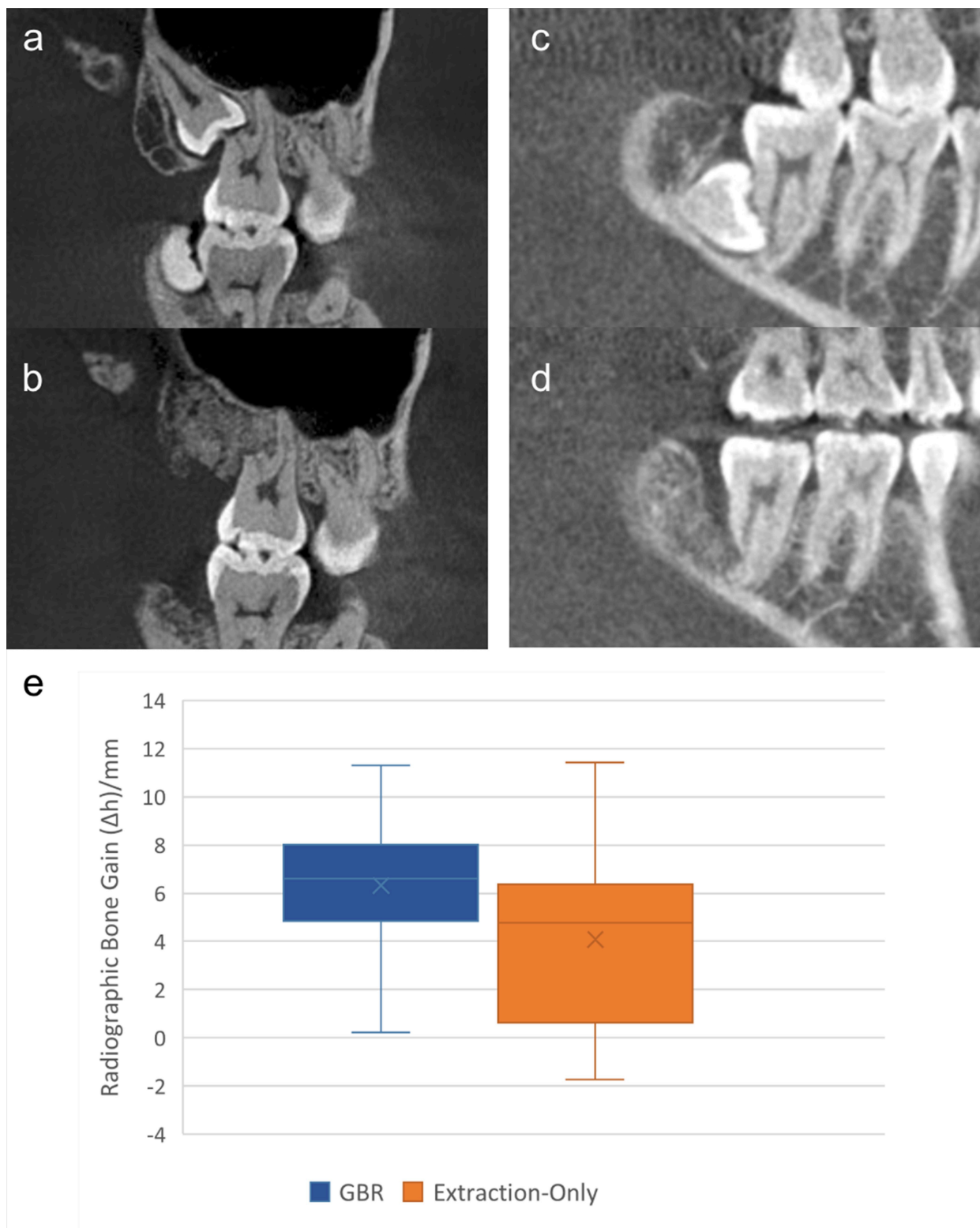


Figure 5

Representative cases and quantitative analysis of distal bone regeneration following M3 extraction with or without GBR.

(a, b) Representative case treated with concurrent GBR: preoperative (a) and 6-month postoperative (b) CBCT views demonstrating substantial distal bone regeneration.

(c, d) Representative case treated with extraction alone: preoperative (c) and 6-month postoperative (d) CBCT views showing cessation of ERR with limited bone recovery.

(e) Box plot of distal bone gain (Δh). The GBR group demonstrated significantly greater bone gain compared with the extraction-only group ($P < 0.05$).