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Flapless technique improves patient-reported outcomes after half-impacted third molar removal: deciphering the mediating role of facial swelling in a prospective cohort

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Abstract

Background: Third molar extraction is one of the most common dentoalveolar procedures. Postoperative pain, swelling, and trismus can impair oral health-related quality of life, making patient-reported outcomes (PROs) a core measure of recovery. Although flapless extraction is considered less invasive than conventional flap surgery, evidence on whether and how it improves PROs in partially impacted mandibular third molars remains limited.

Methods: In this prospective observational cohort, patients treated by the same surgeon were consecutively enrolled and grouped according to the actual technique used: flapless or distal triangular flap. Pain (visual analog scale), facial swelling (Landucci method), and maximal mouth opening were assessed preoperatively and on postoperative days (POD) 1, 3, and 7. PROs were measured with the Oral Health Impact Profile-14 (OHIP-14) on POD7. Between-group differences were analyzed using two-sample comparisons. Generalized linear models (GLMs) were constructed with POD7 OHIP-14 total score as the dependent variable. Mediation analysis using the PROCESS macro estimated the total effect, direct effect, and indirect effect of surgical technique on PROs through each clinical mediator.

Results: A total of 216 patients were enrolled (flapless, n = 95; flap, n = 121). At POD1, 3, and 7, mouth opening change, facial swelling change, and VAS pain score were significantly lower in the flapless group than in the flap group ($P < 0.05$). The POD7 OHIP-14 total score was significantly lower in the flapless group ($P < 0.05$). In GLMs, flapless technique remained associated with a lower OHIP-14 score after adjustment in the POD1 model ($P < 0.001$) and the POD7 model ($P < 0.001$); in the POD3 model, the association was attenuated ($P = 0.054$). Mediation analysis identified POD3 facial swelling as the dominant mediator: the indirect effect was 4.7191, accounting for 67.25% of the total effect. Pain and trismus mediated smaller proportions (POD3 pain, 15.28%; POD3 mouth opening, 14.03%; POD7 pain, 8.86%; POD7 mouth opening, 13.72%).

Conclusions: The flapless technique improved POD7 PROs after extraction of partially impacted mandibular third molars, primarily by reducing POD3 facial swelling. These observational findings require confirmation by randomized controlled trials.

Introduction

Third molar (M3) extraction is one of the most common procedures in dentoalveolar surgery [1]. It is frequently accompanied by postoperative pain, swelling, trismus, local infection, and inferior alveolar nerve dysfunction [2]. These complications can impair eating, sleep, and daily activities and are therefore strongly associated with quality of life. Identifying factors that shape patients' subjective recovery is thus an urgent clinical issue.

In recent years, patient-reported outcomes (PROs) have become a core subjective measure of the overall postoperative experience. Unlike objective clinical findings, PROs more directly reflect patients' physical and psychological perceptions during recovery [3]. Validated patient-reported outcome measures (PROMs) allow efficient, standardized monitoring of these perceptions. In this study, the Oral Health Impact Profile-14 (OHIP-14) was selected to quantify oral health-related quality of life, including pain and oral function [4].

For mandibular M3 extraction, a full-thickness mucoperiosteal flap is conventionally used to provide surgical access and remove bone resistance [5]. Although convenient intraoperatively, it may increase postoperative swelling, pain, oozing, and the risk of wound infection or dehiscence [6]. Modified limited-flap techniques have been

developed to reduce surgical trauma, but extensive gingival detachment can still cause postoperative sequelae. The flapless technique avoids a vertical releasing incision and extensive mucoperiosteal elevation, or uses only a small mesial oblique incision (1–3 cm). By preserving soft-tissue blood supply, it may reduce inflammatory responses [7]. Although some studies suggest clinical benefits, evidence is not entirely consistent, and its effect on PROs and the pathways involved remain unclear [7, 8].

To address this gap, this prospective observational cohort compared the flapless technique with the conventional distal triangular flap in patients with partially impacted mandibular M3s. We assessed postoperative PROs using the OHIP-14 and constructed generalized linear models (GLMs) to estimate associations between PROs and clinical indicators—swelling, pain, and trismus—after adjusting for demographic factors and baseline characteristics of the affected and adjacent teeth. Mediation analysis was then performed to test whether these indicators mediated the relationship between surgical technique and PROs and to quantify each mediating pathway. This study aimed to clarify how the flapless technique may influence PROs and to provide preliminary evidence for minimally invasive extraction of partially impacted mandibular M3s.

Methods

Study Population

This prospective study included patients who visited the same surgeon at the Department of Oral Surgery, West China Hospital of Stomatology, Sichuan University, from 2024 October to March 2026. All patients were fully informed of the study protocol and procedures, provided informed consent, and voluntarily participated. The study was approved by the Ethics Committee of West China Hospital of Stomatology, Sichuan University (approval number: WCHSIRB-D-2024-297) and was conducted in strict accordance with the Declaration of Helsinki. Before enrollment, each patient underwent a specialized oral examination and radiographic evaluation and was screened against the following inclusion and exclusion criteria based on medical history [9].

Inclusion criteria: (1) requiring extraction of a partially impacted mandibular M3; (2) absence of infection at the tooth indicated for extraction within three days before the procedure; (3) well-controlled systemic condition(s) with no absolute or relative contraindications to tooth extraction; (4) ability to understand the questionnaire and provide informed consent independently, or with the assistance of a guardian.

Exclusion criteria: (1) presence of systemic disease(s) or long-term medication use that could affect pain assessment; (2) contraindications to oral surgical procedures; (3) poorly controlled psychiatric disorder(s).

This prospective, single-center, single-surgeon, non-randomized observational cohort study was conducted between October 2024 and March 2026. Consecutive patients requiring extraction of a partially impacted mandibular third molar were screened for eligibility. Eligible patients were allocated to two groups according to a time-block design: those enrolled from October 2024 to June 2025 underwent flapless extraction, whereas those enrolled from July 2025 to March 2026 underwent distal triangular flap extraction. The surgical technique was therefore determined by the enrollment period and was not randomly assigned. If intraoperative difficulties prevented completion of the flapless procedure, the surgeon converted to a distal triangular flap according to routine clinical practice; these patients were classified into the flap group according to the as-treated principle. The number of conversions and the reasons were recorded. The primary analysis followed the as-treated principle. Sensitivity analyses were performed according to the initial allocation and after excluding conversion

cases.Sample size was calculated based on the formula for comparing two proportions in a 1:1 cohort study. A two-sided α of 0.005 and a statistical power of 80% were set. According to previous literature, the event rate was estimated to be 40% in the non-exposed group and 68% in the exposed group. The required sample size was 78 participants per group. Accounting for an expected 15% loss to follow-up, 90 subjects in each group were planned for this study.(Fig. 1).

Flapless extraction[10] was performed under local anesthesia. The crown was sectioned using a high-speed turbine handpiece and then removed in segments, after which the root was elevated in a minimally traumatic manner. The buccal and lingual periosteum and muscle attachments were preserved throughout the procedure.In this study, flapless extraction of the third permanent molar was primarily performed under local anesthesia using a 45-degree high-speed turbine handpiece with a sectioning bur. A horizontal oblique cut was first made from the maximum prominence of the buccal crown toward the deep lingual aspect, extending to near the pulp chamber and reaching above the root bifurcation, to section and elevate the crown. A dental elevator was then used to loosen the root, and the tooth was extracted. When considerable root resistance was encountered, the bur was applied at the center of the previously created horizontal groove to make a vertical downward cut along the root bifurcation groove, splitting the root into separate mesial and distal roots. The cut was terminated below the root bifurcation without penetrating the apex, and all roots were removed separately. Finally, the extraction socket was debrided, filled with absorbable gelatin sponge containing colloidal silver, and the wound was closed with interrupted sutures for hemostasis.No patients received prophylactic antibiotics preoperatively.(Fig. 2). Postoperatively, in the absence of a history of cephalosporin allergy, cefaclor capsules 0.25 g were routinely administered three times daily for 3 days, together with diclofenac sodium sustained-release capsules 50 mg twice daily for 3 days. In patients with a history of cephalosporin allergy, amoxicillin capsules 0.5 g were given twice daily for 3 days. No hormonal agents or mouthwashes were used. Ice packs were applied within 24 hours after surgery. All patients received uniform standardized post-extraction instructions, and postoperative care measures were identical.

Assessment of Postoperative Pain, Swelling, Mouth Opening, and Quality of Life

Postoperative pain was assessed using the visual analog scale (VAS) [11]. Patients were asked to indicate their pain level on a 10-cm horizontal line, with the left endpoint labeled “no pain” and the right endpoint labeled “worst imaginable pain.” The distance (in cm) from the “no pain” end to the patient’s mark was recorded as the pain score, which ranged from 0 to 10, with higher scores representing greater pain intensity. Pain assessments were completed on postoperative days 1, 3, and 7.

Facial swelling was measured using the Landucci method [12]. With the patient seated upright, three distances were measured with a non-elastic soft tape: tragus–mouth corner (T-MC), tragus–ala nasi (T-AL), and gonion–ala nasi (G-AL). The three distances were summed to obtain S. Measurements were taken preoperatively and on postoperative days 1, 3, and 7. The facial swelling change (ΔS, in mm) at each time point was defined as the difference between the postoperative sum and the preoperative baseline sum. All measurements were performed twice by a single calibrated evaluator, and the mean value was used.[13]

Maximal mouth opening (MMO) was assessed with the patient seated upright, instructed to open the mouth maximally. The vertical distance between the incisal edges of the maxillary and mandibular right central incisors was measured using a digital caliper. Each measurement was repeated twice and averaged, and the value was

recorded in millimeters (mm). The preoperative MMO served as the baseline. The mouth opening change (ΔM) at each postoperative time point (days 1, 3, and 7) was calculated as the difference between the postoperative measurement and the baseline MMO.

To capture postoperative patient-reported outcomes (PROs) more accurately, the Oral Health Impact Profile-14 (OHIP-14) was administered as the quality of life (QoL) instrument [14].The Oral Health Impact Profile-14 (OHIP-14) consists of 14 items covering 7 domains, namely functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap, with 2 items in each domain. Each item is scored on a 5-point Likert scale (0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, 4 = very often) to assess the frequency of oral health-related impacts on quality of life over the past month. The total score is obtained by summing the scores of all items, ranging from 0 to 56, with higher scores indicating poorer oral health-related quality of life. In this study, patients completed the questionnaire via the Wenjuanxing mobile application on postoperative day 7, and the scores for each item were recorded. Submission was permitted only after all items had been completed, so there were no missing responses.This study was reported in adherence to the STROBE statement for cohort studies. The completed STROBE checklist is available as supplementary material.

Statistical Analysis

All statistical analyses were performed using SPSS version 27.0. Data were analyzed according to the actual procedure received, following an as-treated principle. Individuals with missing data for any reason were excluded from the analysis. For baseline demographic characteristics, the Mann–Whitney U test was used for the comparison of education and age between cohorts, and the chi-square was used for all other baseline variables. Postoperative OHIP-14 scores were compared between cohorts using the Mann–Whitney U test.

A generalized linear model (GLM) with a normal distribution and identity link was constructed with the patient-reported outcome measure (OHIP-14 score) as the dependent variable, flap technique as the factor, and demographic baseline factors, clinical characteristics of the involved tooth, postoperative pain, postoperative swelling, and postoperative mouth opening as covariates. Herein, separate GLMs were constructed, with POD7 OHIP-14 as the outcome and POD1, POD3, or POD7 clinical variables entered, respectively.

Mediation analysis was subsequently performed using Model 4 of the PROCESS macro (version 4.1) for SPSS, with the OHIP-14 score specified as the outcome variable (Y), flap technique as the independent variable (X), and postoperative pain, postoperative swelling, and postoperative mouth opening specified as mediators (M). Demographic and tooth-related variables were included as covariates. The effect of X on M (path a), the effect of M on Y (path b), and the total effect of X on Y (path c) were estimated. The direct effect of X on Y after controlling for the mediators (path c') was calculated as $c' = c - a \times b$, where $a \times b$ represents the indirect effect of X on Y through the mediators. A bootstrap procedure with 5000 resamples was used to calculate the 95% confidence intervals for the direct and indirect effects. An effect was considered statistically significant if its 95% confidence interval did not include zero. No fixed seed was specified, and no bias correction was applied.

Results

Baseline Characteristics

A total of 216 participants were ultimately enrolled in this cohort study, including 95 in the flapless cohort and 121 in the distal triangular flap cohort. No significant difference in gender, age, education level, household registration

was observed (P > 0.05). Regarding impacted tooth and adjacent tooth factors, no significant differences were found in Winter's classification, Pell and Gregory classification, the presence of caries on the M3, the presence of defects on the adjacent second molar, or the proportion of patients with ≥50% distal bone loss (P > 0.05). These results indicate that the baseline demographic characteristics and preoperative clinical and radiographic features were well balanced between the two cohorts, supporting their comparability for subsequent efficacy analyses (Table 1).

Postoperative Pain, Swelling, and Mouth Opening

On postoperative day 1, mouth opening change, facial swelling change, and VAS pain score were all significantly lower in the flapless cohort than in the flap cohort (P < 0.0001), indicating that the flapless technique was associated with less early postoperative trismus, soft tissue swelling, and pain.

On postoperative day 3, the differences between the two cohorts in mouth opening, swelling, and VAS pain score remained statistically significant (all P < 0.0001), with lower values in the flapless cohort. This suggests that the flapless cohort still had better functional recovery and inflammatory control during the mid-postoperative period.

By postoperative day 7, both cohorts showed marked reductions in mouth opening change and swelling change compared with the early postoperative period; however, these parameters remained significantly lower in the flapless cohort than in the flap cohort (both P < 0.0001). VAS pain scores approached low levels in both cohorts, but the flapless cohort still had a significantly lower pain score (P = 0.0018). Overall, the flapless technique was associated with less trismus, facial swelling, and pain at days 1, 3, and 7 after surgery, suggesting that it provides meaningful clinical improvement in symptoms following mandibular M3 extraction (Figure 3).

Relationship Between Flap Technique and Postoperative QoL

The Mann–Whitney U test was used to compare OHIP-14 item scores and total scores between the two cohorts on postoperative day 7. The total OHIP-14 score in the flapless cohort (median 7, IQR 4–9) was significantly lower than that in the flap cohort (median 14, IQR 9–18.5; P < 0.001), indicating less impairment in oral health-related quality of life in patients treated with the flapless technique.(Table2)

Among the domains related to oral function and pain, significant differences were observed for several items. For worsened sense of taste, the median score was 0 (IQR 0–1) in the flapless cohort and 1 (IQR 1–2) in the flap cohort (P < 0.001). For painful aching in the mouth, the median score was 1 (IQR 1–2) in the flapless cohort and 3 (IQR 2–4) in the flap cohort (P < 0.001). For uncomfortable to eat, the median score was 1 (IQR 1–2) in the flapless cohort and 3 (IQR 1.5–3) in the flap cohort (P < 0.001). For unsatisfactory diet, the median score was 1 (IQR 0–2) in the flapless cohort and 2 (IQR 2–3) in the flap cohort (P < 0.001). For interrupted meals, the median score was 1 (IQR 0–2) in the flapless cohort and 3 (IQR 2–3) in the flap cohortP<0.001).These findings suggest that the flapless technique was associated with less postoperative pain and fewer eating-related limitations.

In addition, the distribution of scores for trouble pronouncing words differed significantly between the two cohorts(P=0.029).Significant differences were also found for feeling tense(P=0.003),difficulty doing usual jobs (*P* = 0.003),and being totally unable to function(P=0.001).It should be noted that for some of these items the median values were identical between the two cohorts, indicating that the overall score distributions differed, although the direction and clinical magnitude of the difference cannot be fully determined from medians and interquartile ranges alone.

No significant differences were observed for the items concerning self-consciousness, difficulty relaxing, embarrassment, irritability, or the perception that life in general was less satisfying (all P > 0.05). Overall, the flapless technique mainly alleviated pain, taste disturbances, eating discomfort, and diet-related complaints on postoperative day 7, and was reflected in a lower total OHIP-14 score.

Associations Between Postoperative Clinical Parameters and OHIP-14 Scores

Prediction model using postoperative day 1 variables

With the total OHIP-14 score on postoperative day 7 (POD7) as the dependent variable, surgical technique, demographic characteristics, impacted tooth-related features, and postoperative day 1 (POD1) pain, swelling, and mouth opening change were entered into a generalized linear model. After adjusting for confounders, flap technique was significantly associated with the POD7 OHIP-14 total score (B = −5.484, 95% bootstrap CI: −7.360 to −3.608, P < 0.001), indicating that, compared with the distal triangular flap technique, the flapless technique was associated with a mean reduction of 5.484 points in the total OHIP-14 score.

Age was also negatively associated with the POD7 OHIP-14 total score (B =−0.067, 95% bootstrap CI: −0.127 to −0.006, P=0.031), meaning that with other variables held constant, each one-year increase in age was associated with a mean decrease of 0.067 points in the total OHIP-14 score. The change in the Landucci swelling scale on POD1 was positively associated with the OHIP-14 total score (B=0.307, 95% bootstrap CI: 0.005 to 0.608, P=0.046), suggesting that greater early postoperative swelling was associated with more pronounced impairment in oral health-related quality of life on POD7. None of the other variables—including sex, education level, household registration type, Winter classification, Pell and Gregory classification, caries on the M3, defect on the adjacent second molar, distal bone resorption ≥50%, POD1 VAS pain score, and mouth opening change—showed a significant association with the OHIP-14 total score (all P > 0.05).(Table 3)

Model using postoperative day 3 clinical variables

A generalized linear regression analysis was performed with the POD7 OHIP-14 total score as the dependent variable, including surgical technique, demographic characteristics, impacted tooth-related variables, and POD3 pain, swelling, and mouth opening change as independent variables. Age was negatively associated with the POD7 OHIP-14 total score (B = −0.081, 95% bootstrap CI: −0.136 to −0.025, P = 0.004), indicating that with each one-year increase in age, the mean OHIP-14 total score decreased by 0.081 points, holding other variables constant.

The change in the Landucci swelling scale on POD3 showed a significant positive association with the POD7 OHIP-14 total score (B = 1.294, 95% bootstrap CI: 0.861 to 1.727, P<0.001). After controlling for other factors, a one-unit increase in POD3 swelling change was associated with a mean increase of 1.294 points in the POD7 OHIP-14 total score, suggesting that greater swelling on POD3 was associated with more pronounced impairment in oral health-related quality of life on POD7.

The association between flap technique and the OHIP-14 total score did not reach statistical significance (B = −1.843, 95% bootstrap CI: −3.715 to 0.029, P = 0.054). In addition, sex, education level, household registration type, Winter classification, Pell and Gregory classification, caries on the M3, defect on the adjacent second molar, distal bone resorption ≥50%, POD3 VAS pain score, and mouth opening change were not significantly associated with the POD7 OHIP-14 total score (all P > 0.05).(Table 4)

Model using postoperative day 7 clinical variables

In the generalized linear regression model that included postoperative day 7 clinical variables, flap technique remained significantly associated with the POD7 OHIP-14 total score (B = −4.614, 95% bootstrap CI: −6.077 to −3.151, P < 0.001).

Age was again negatively associated with the OHIP-14 total score (B = −0.075, 95% bootstrap CI: −0.131 to −0.019, P = 0.009). In addition, both the POD7 VAS pain score (B = 2.515, 95% bootstrap CI: 0.634 to 4.397, P = 0.009) and the POD7 Landucci swelling scale change (B = 1.487, 95% bootstrap CI: 0.897 to 2.077, P < 0.001) were significantly and positively associated with the OHIP-14 total score. Specifically, each one-unit increase in the VAS pain score and swelling change was associated with a mean increase of 2.515 and 1.487 points in the total OHIP-14 score, respectively, indicating that more severe pain and swelling on POD7 were associated with greater impairment in oral health-related quality of life.

Sex, education level, household registration type, Winter classification, Pell and Gregory classification, caries on the M3, defect on the adjacent second molar, distal bone resorption ≥50%, and POD7 mouth opening change were not significantly associated with the POD7 OHIP-14 total score (all P > 0.05).(Table 5)

Mediation Analysis of Flap Technique and Postoperative OHIP-14 Score

Using surgical technique as the independent variable (flapless cohort coded as 1, flap cohort coded as 2) and the POD7 OHIP-14 total score as the dependent variable, mediation analysis was performed. The total effect of surgical technique on the POD7 OHIP-14 total score was significant (c = 7,0171, P< 0.01). This positive total effect indicates that, compared with the flapless technique, the flap technique was associated with a higher POD7 OHIP-14 total score, reflecting greater impairment in postoperative oral health-related quality of life.

Among the POD1 variables, surgical technique showed significant positive associations with the VAS pain score (a = 0.7220, P< 0.01), mouth opening change (a = 2.9766, P< 0.01), and Landucci swelling scale change (a = 2.8671, P< 0.01), indicating that patients in the flap cohort experienced more severe early pain, trismus, and swelling. The POD1 VAS pain score (b = 0.9006, P = 0.0199) and Landucci swelling change (b = 0.3898, P= 0.0091) were both positively associated with the POD7 OHIP-14 total score. After including these mediators, the direct effects of surgical technique on the OHIP-14 total score remained significant (c' = 6.3668 and 5.8994, respectively, both P < 0.01), suggesting that POD1 pain and swelling partially mediated the relationship between surgical technique and postoperative QoL. The association between POD1 mouth opening change and the POD7 OHIP-14 total score was not statistically significant (b=0.1105, P=0.5733), providing no evidence of a mediating effect.

In the mediation model incorporating POD3 variables, the total effect of surgical technique on the POD7 OHIP-14 total score was significant (P< 0.01). Consistent with the cohort coding (flapless cohort = 1, flap cohort = 2), the flap technique was associated with a higher POD7 OHIP-14 total score, indicating greater impairment in postoperative oral health-related quality of life.(Table 6)

Mediation Analysis (Continued)

Surgical technique was significantly positively associated with the POD3 VAS pain score (a = 0.8072, P < 0.01), and the POD3 VAS pain score was significantly positively associated with the POD7 OHIP-14 total score (b = 1.3279, P < 0.01). After including the POD3 VAS pain score, the direct effect of surgical technique on the POD7 OHIP-14 total score remained significant (c' = 5.9452, P < 0.01), suggesting that POD3 pain partially mediated the relationship between surgical technique and postoperative day 7 oral health-related quality of life. The indirect

effect, calculated as a × b (0.8072 × 1.3279), was approximately 1.0719, which was consistent with the difference between the total and direct effects.

Surgical technique also showed a significant positive association with POD3 mouth opening change (a = 3.1614, P < 0.01). POD3 mouth opening change was positively associated with the POD7 OHIP-14 total score (b = 0.3113, P = 0.0458). After controlling for this variable, the direct effect of surgical technique remained significant (c' = 6.0329, P < 0.01), indicating that POD3 trismus may partially mediate the effect of surgical technique on POD7 oral health-related quality of life.

Furthermore, surgical technique was significantly positively associated with the POD3 Landucci swelling scale change (a = 3.2209, $P<0.01$), and POD3 swelling change was significantly positively associated with the POD7 OHIP-14 total score (b = 1.4652, $P<0.01$). After controlling for POD3 swelling change, the direct effect of surgical technique was reduced but remained statistically significant (c' = 2.2979, P = 0.0138), suggesting that POD3 swelling may be a relatively major partial mediator of the effect of surgical technique on the POD7 OHIP-14 total score. In summary, POD3 pain, trismus, and swelling may all be involved in the association between surgical technique and postoperative day 7 oral health-related quality of life, with swelling playing a comparatively more prominent mediating role.

Among the POD7 variables, the flap technique (coded as 2) was associated with a higher VAS pain score (a = 0.1542, P = 0.0014), greater mouth opening change (a = 1.0741, P < 0.01), and greater Landucci swelling scale change (a = 1.0741, P < 0.01). The POD7 VAS pain score (b = 4.0291, P < 0.01), mouth opening change (b = 0.8962, P = 0.0119), and Landucci swelling scale change (b = 1.7520, P < 0.01) were all significantly positively associated with the POD7 OHIP-14 total score. After controlling for the respective mediators, the direct effects of surgical technique remained significant (c' = 6.3956, 6.0545, and 5.1548, respectively, all P < 0.01). These findings indicate that POD7 pain, trismus, and swelling may each partially mediate the effect of surgical technique on postoperative oral health-related quality of life. (Figure 4)

Discussion

In routine dentoalveolar practice, the evaluation framework for third molar extraction outcomes has gradually shifted over time from clinician-observed complications towards patient-reported quality of life, with growing emphasis on psychological empathy, information exchange, shared decision-making, and social functional recovery. This trend has established patient-reported outcomes (PROs) as a pivotal endpoint in assessing surgical success [15, 16]. However, previous studies comparing flap versus flapless techniques have largely confined their analyses to between-group differences in objective parameters such as pain VAS, facial swelling in millimetres, and mouth opening [17, 18], and no investigation to date has integrated the surgical approach, objective clinical responses, and PROs within a unified analytical framework, nor has any elucidated the specific pathways through which the surgical technique affects patients' subjective perceptions.

To address this gap, we established a prospective cohort and, for the first time, combined generalized linear models (GLMs) for confounder adjustment with PROCESS mediation analysis to quantify the relative weights of potential mediators, thereby systematically dissecting the mechanisms underlying the influence of the flapless technique on the POD7 OHIP-14 total score. Our findings revealed that the median OHIP-14 total score in the flapless group was 7 points lower than that in the flap group. Notably, this advantage was not driven solely by pain reduction, but was predominantly mediated by facial swelling on postoperative day 3 (indirect effect accounting

for 67.25% of the total effect), which for the first time identifies swelling control as a central hub in the PRO improvement pathway.

To better understand how the flapless technique translates into PRO benefits, it is essential to map each of the three major postoperative clinical symptoms onto specific OHIP-14 domains, for which our between-group item-level comparisons provide direct evidence. Pain (VAS) primarily undermined physiological pain perception and eating function—the items showing the largest intergroup differences were “painful aching in the mouth”, “uncomfortable to eat”, and “unsatisfactory diet”, suggesting that pain directly compromises patients’ basic physical well-being. Facial swelling, although not directly corresponding to any single OHIP-14 item, may affect quality of life indirectly through altered appearance and psychological tension. Indeed, the items “felt tense” and “difficulty relaxing” (though not reaching statistical significance, showing a consistent trend) could be partly attributable to social avoidance and heightened self-awareness induced by swelling, which also explains why swelling exhibited the largest mediating effect—it operates through both physiological and psychological pathways. Trismus (mouth opening change) predominantly influenced speech and role functioning, as evidenced by significant between-group differences in “trouble pronouncing words” and “difficulty doing usual jobs”, indicating that mechanical restriction of mouth opening directly interferes with occupational and social activities. Furthermore, the GLM regression coefficients consistently showed that the β coefficient for POD3 swelling (1.294) was substantially larger than those for POD3 VAS (0.551) and mouth opening change (0.178), and swelling remained the strongest predictor $\beta = 1.487$ even when POD7 variables were included in the model, thereby establishing swelling as the primary therapeutic target for PRO optimisation.

The flapless technique avoids a vertical releasing incision and extensive periosteal elevation, thereby maximally preserving the blood supply and lymphatic drainage channels of the buccal and lingual soft tissues, which in turn reduces local inflammatory exudation and haematoma formation. This is considered the biological basis for the significantly lower postoperative facial swelling observed in the flapless group at all time points (ΔS, $P < 0.001$ for each). Once swelling is attenuated, tissue tension decreases, which directly alleviates tension-related pain—consistent with the synchronous between-group differences in VAS scores observed in this study. Concurrently, improved soft-tissue compliance relieves mechanical traction on the anterior border of the ramus and the masseter muscle, thereby facilitating mouth opening. Thus, a clear cascade emerges: swelling represents the upstream event, while pain and trismus are downstream manifestations.

Mediation analysis further substantiated this temporal hierarchy. When postoperative day 3 (POD3) variables were entered into the model, the direct effect (c') of surgical technique on the OHIP-14 total score decreased to 2.2979 $P = 0.0138$, whereas the indirect effect (a × b) was 4.7191, accounting for 67.25% of the total effect. This suggests that POD3 swelling largely captures the explanatory pathway linking the surgical approach to PROs. This finding is biologically plausible, as the inflammatory response typically peaks at 48–72 hours postoperatively—the degree of swelling at POD3 appears to set the baseline for subsequent tissue repair, which in turn influences patients’ global assessment of recovery at POD7. In comparison, the mediation proportion through POD1 swelling was only 15.93%, and that through POD7 swelling was 26.54%, further reinforcing the notion that the mid-postoperative period (POD3) represents the most critical time window through which the surgical technique exerts its impact on PROs. These observations imply that, if further improvement in PROs is to be pursued on top of the flapless technique, targeted anti-oedema interventions should be prioritised during the 48 to 72 hour window, rather than focusing solely on immediate postoperative analgesia.

Despite the overall between-group differences, the OHIP-14 total scores within the flapless group still exhibited considerable variation (IQR 4–9), and a small number of patients required intraoperative conversion to the flap approach. These findings indicate that the flapless technique may not be universally suitable for all cases of partially impacted mandibular third molars, and careful selection of indications is warranted.

In the present study, the cases that required intraoperative conversion to the flap technique (n = 3; see Supplemental Table S1) shared several common features: relatively profuse intraoperative bleeding and root morphology with a clasping configuration that precluded effective separation, making it unsafe to complete tooth sectioning or bone removal under the limited visualization afforded by the flapless approach. Forced manipulation in such circumstances might have increased the risk of root displacement or inferior alveolar nerve injury. The postoperative swelling and VAS scores in these patients were comparable to those in the flap group, suggesting that anatomical complexity effectively offset the presumed minimally invasive advantage of the flapless technique.

Regarding host factors, the GLM revealed that each one-year increase in age was associated with a decrease of 0.067–0.081 points in the OHIP-14 total score, indicating that younger patients tended to report worse PROs. This association may be partly attributable to a more robust inflammatory immune response in younger individuals—resulting in more pronounced swelling—as well as potentially higher expectations regarding social and functional recovery, rather than solely to differences in tissue healing capacity per se. These observations imply that more judicious indication selection and enhanced perioperative management may be particularly important in younger patients.

Taken together, the optimal indications for the flapless technique may be guided by the criteria summarised in the systematic review by Al-Moraissi et al. [19]: (1) preoperative CBCT or panoramic radiography showing adequate bone access around the crown; (2) the feasibility of circumferential bone removal via the alveolar crest and tooth sectioning; (3) absence of acute pericoronitis; and (4) non-deep impaction without significant anatomical variation of the inferior alveolar nerve. Conversely, for complex scenarios such as widely divergent roots, thick buccal cortical bone, or low-lying mesioangular impactions, the flapless approach should not be pursued at the expense of safety; rather, a conventional flap should be promptly adopted with safety as the overriding principle. Our data provide direct PRO-based evidence to support this stratified decision-making approach.

Consistent with the findings of Al-Delayme et al. [20] and Badiali et al. [13], our study also confirmed the significant advantages of the flapless technique in reducing postoperative pain, swelling, and trismus.

Although Ribeiro et al. [7] reported improvements in PROs with the flapless approach, their analyses were confined to total score comparisons without disentangling the mechanisms underlying these improvements or identifying the pathways involved, nor did they adjust for baseline anatomical confounders.

The core breakthrough of the present study lies in the first-time construction of a mediation chain linking the surgical approach (X) → objective clinical symptoms (M) → PROs (Y), with quantification of the relative weights of each pathway and identification of the dominant mediating role of swelling on postoperative day 3. This analytical framework moves clinicians beyond the mere knowledge that the flapless technique is “better” to an understanding of why it is better and at which time point specific interventions might further amplify the benefits. Moreover, by adjusting for seven baseline confounders—including Winter classification, Pell–Gregory

classification, and adjacent tooth status—through GLM, we minimised potential bias inherent in observational studies, thereby strengthening the evidence base for causal inference.

To maximise PRO gains, we advocate a combined strategy with the flapless technique as the cornerstone and perioperative targeted anti-oedema interventions—for example, piezoelectric bone surgery to reduce thermal osteonecrosis [21], intravenous dexamethasone (8 mg) immediately upon completion of the procedure, regular ice application during the first 48 hours, and a standard postoperative NSAID regimen [22]. In addition, non-surgical factors such as postoperative sleep quality (as investigated by Hu et al. [23]) and good humanistic communication and care [16, 22] may also modulate PROs, suggesting that future efforts should incorporate multidimensional interventions to establish a “bio-psycho-social” comprehensive management model.

Given the age-related heterogeneity observed, we suggest that stricter indication selection and more intensive postoperative follow-up be considered for patients aged ≤ 30 years, whereas a slightly broader indication range may be acceptable for those aged > 40 years.

Several limitations should be acknowledged. This study was a single-centre, single-surgeon observational cohort; although we employed concurrent enrolment and statistical adjustments, the possibility of residual confounding cannot be entirely excluded, and causal inference awaits confirmation by well-designed randomised controlled trials. We did not assess baseline psychological or behavioural factors—such as anxiety levels, pain catastrophising tendencies, or sleep quality—which may partly account for the age-related differences and the residual heterogeneity within groups. Furthermore, the OHIP-14 was administered only on POD7, thereby failing to capture the dynamic recovery trajectory (e.g., the acute phase on POD1–3 versus functional recovery on POD14). Future studies could employ daily electronic diaries to collect longitudinal PRO data.

Conclusions

In summary, compared with the flap technique, the flapless technique for extraction of partially impacted mandibular third molars significantly improved oral health-related quality of life at postoperative day 7, as reflected by a 7-point reduction in the OHIP-14 total score. This improvement was predominantly mediated by reduced facial swelling on POD3 (indirect effect accounting for 67.25% of the total effect), with pain and trismus playing secondary roles. Our findings provide a clear mechanistic rationale for clinical practice: controlling mid-phase swelling is the central target for optimising PROs, and the flapless technique should be judiciously applied to cases with moderate-to-high impaction and adequate pericoronal bone access, avoiding forcible use in anatomically complex scenarios. Although confirmation through RCTs is warranted, this study offers PRO-based evidence to inform clinicians’ decision-making in minimally invasive extraction, thereby facilitating a paradigm shift in third molar surgery from “technical success” towards “patient satisfaction.”

Declarations

Ethics approval and consent to participate

The research was approved by the Ethics Committee of West China Hospital of Stomatology (No. WCHSIRB-D-2024-297). All participants involved in the research have provided their informed consent and are independent of any external influences.

Consent for publication

Written informed consent was obtained from the participant for publication of their de-identified intraoral clinical photograph. The participant was informed that the photograph would be used for this study and published in a peer-reviewed journal.

Competing interests

Yubin Cao is the Editorial Board Member of the BMC Oral Health.

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Author Contribution

Z.Y., L. H., Y. B., and J. P. designed the study. L. H., and L. Y. collected data. Z. Y., and L. H. analyzed the data. L. W. and Y. B. designed the questionnaire. Z. Y. and L. H. wrote the manuscript, Y. B. and J. P. revised the manuscript. Y. B. and J. P. supervised the whole project.

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Not applicable.

Availability of data and materials

Data used to support the findings of this study are available from the corresponding author upon request.

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Tables

Table1. General population characteristics involved in this study

Population Characteristics		**Total (N=216)**	**Flapless (N=95)**	**Triangular-Distal (N=121)**	**P**
Gender	Male	110	49	61	0.865
	Female	106	46	60	
Age (y)			30.7±10.2	30.7±11.6	0.509
Education	Primary and below	2	0	2	0.624
	Junior high	9	4	5	
	Senior high	57	26	31	
	College	115	53	62	
	Graduate and higher	33	12	21	
Household registration type	Urban household registration	195	85	110	0.724
	Non-urban household registration	21	10	11	
Winter’s classification	Mesioangular	154	67	87	0.825
	Horizontal	62	28	34	
Pell-Gregory classification	High impact	86	38	48	0.961
	Medium impact	130	57	73	
M3 caries	Yes	41	18	23	0.991
	No	175	77	98	
Defect on adjacent M2	Yes	66	30	36	0.772
	No	150	65	85	
Distal bone loss ≥50%	Yes	45	20	25	0.944
	No	171	75	96	

Note. P value for Education and Age: two-tailed Mann-Whitney U test ; all other P values: chi-square test. M3: third molar. M2: second molar.

Table 2. Mann-Whitney U TEST for postoperative day 7 OHIP-14 scores

Variable	Flapless (n = 95)	Flap (n = 121)	Z	P
Have you had trouble pronouncing any words because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,0)	2.185	0.029
Have you felt that your sense of taste has worsened because of problems with your teeth, mouth, or dentures?	0(0,1)	1(1,2)	6.091	0.000
Have you had painful aching in your mouth?	1(1,2)	3(2,4)	8.481	0.000
Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth, or dentures?	1(1,2)	3(1.5,3)	7.695	0.000
Have you been self-conscious because of your teeth, mouth, or dentures?	0(0,1)	0(0,1)	1.695	0.090
Have you felt tense because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,1)	2.927	0.003
Has your diet been unsatisfactory because of problems with your teeth, mouth, or dentures?	1(0,2)	2(2,3)	8.084	0.000
Have you had to interrupt your meals because of problems with your teeth, mouth, or dentures?	1(0,2)	3(2,3)	7.168	0.000
Have you found it difficult to relax because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,0)	0.721	0.471
Have you been a bit embarrassed because of problems with your teeth, mouth, or dentures?	0(0,1)	0(0,1)	0.808	0.419
Have you been a bit irritable with other people because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,0)	0.134	0.894
Have you had difficulty doing your usual jobs because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,1)	2.957	0.003
Have you felt that life in general was less satisfying because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,0)	1.674	0.094
Have you been totally unable to function because of problems with your teeth, mouth, or dentures?	0(0,0)	0(0,0)	3.263	0.001
POD7 OHIP-14 total score	7(4,9)	14(9,18.5)	8.421	0.000

Table 3 Generalized linear model of postoperative day 1 measures predicting postoperative day 7 OHIP-14 scores

Note. M3: third molar. M2: second molar.POD:postoperative day

Variables	B	SE	BootLLCI	BootULCI	Wald χ^2	p
Flap technique	-5.484	0.9573	-7.360	-3.608	32.819	0.000
Gender	-0.739	0.6645	-2.042	0.563	1.238	0.266
Age	-0.067	0.0308	-0.127	-0.006	4.678	0.031
Education	0.630	0.4382	-0.229	1.489	2.065	0.151
Household registration type	1.447	1.1439	-0.795	3.689	1.600	0.206
Winter’s classification	0.303	0.7337	-1.135	1.741	0.171	0.679
Pell-Gregory classification	0.575	0.6819	-0.761	1.912	0.712	0.399
M3 caries	-0.447	0.8566	-2.126	1.232	0.272	0.602
Defect on adjacent M2	-0.176	0.7271	-1.601	1.249	0.059	0.809
Distal bone loss ≥50%	-0.539	0.8160	-2.138	1.060	0.436	0.509
POD1 VAS pain score	0.594	0.4004	-0.191	1.378	2.199	0.138
POD1 Landucci swelling scale change	0.307	0.1538	0.005	0.608	3.975	0.046
POD1 mouth opening change	0.076	0.1881	-0.293	0.444	0.162	0.687

Table 4 Generalized linear model of postoperative day 3 measures predicting postoperative day 7 OHIP-14 scores

Variables	B	SE	BootLLCI	BootULCI	Wald χ^2	p
Flap technique	-1.843	0.9550	-3.715	0.029	3.724	0.054
Gender	-0.907	0.6017	-2.086	0.272	2.272	0.132
Age	-0.081	0.0283	-0.136	-0.025	8.165	0.004
Education	0.175	0.4002	-0.610	0.959	0.190	0.663
Household registration type	0.921	1.0508	-1.139	2.980	0.768	0.381
Winter’s classification	0.332	0.6691	-0.979	1.644	0.247	0.620
Pell-Gregory classification	0.146	0.6196	-1.068	1.361	0.056	0.813
M3 caries	-0.594	0.7722	-2.107	0.920	0.591	0.442
Defect on adjacent M2	-0.079	0.6583	-1.369	1.211	0.014	0.905
Distal bone loss ≥50%	-0.488	0.7424	-1.943	0.967	0.432	0.511
POD3 VAS pain score	0.551	0.3334	-0.103	1.204	2.729	0.099
POD3 Landucci swelling scale change	1.294	0.2209	0.861	1.727	34.315	0.000
POD3 mouth opening change	0.178	0.1367	-0.090	0.446	1.688	0.194

Note. M3: third molar. M2: second molar.POD:postoperative day

Table 5 Generalized linear model of postoperative day 7 measures predicting postoperative day 7 OHIP-14 scores

Variables	B	SE	BootLLCI	BootULCI	Wald χ^2	p
Flap technique	-4.614	0.7464	-6.077	-3.151	38.217	0.000
Gender	-0.594	0.6224	-1.814	0.626	0.912	0.340
Age	-0.075	0.0287	-0.131	-0.019	6.863	0.009
Education	0.110	0.4144	-0.703	0.922	0.070	0.791
Household registration type	1.316	1.0596	-0.761	3.392	1.542	0.214
Winter’s classification	0.234	0.6785	-1.096	1.564	0.119	0.730
Pell-Gregory classification	0.149	0.6287	-1.084	1.381	0.056	0.813
M3 caries	-0.738	0.7850	-2.277	0.801	0.884	0.347
Defect on adjacent M2	-0.081	0.6704	-1.395	1.233	0.015	0.904
Distal bone loss ≥50%	-0.731	0.7556	-2.212	0.750	0.936	0.333
POD7 VAS pain score	2.515	0.9600	0.634	4.397	6.866	0.009
POD7 Landucci swelling scale change	1.487	0.3011	0.897	2.077	24.391	0.000
POD7 mouth opening change	0.404	0.3305	-0.243	1.052	1.497	0.221

Note. M3: third molar. M2: second molar.POD:postoperative day

Table 6: Mediation Analysis of Flap Technique on Postoperative OHIP-14 Score.

Mediator(s) M	Mediation model effects	Coeff	Boot SE	T	P	BootLLCI	BootULCI	Proportion mediated
POD1 VAS pain score	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	6.3668	0.7390	8.6151	0.0000	4.9097	7.8240	90.73%
	Indirect effect	0.6502	0.3333			0.0892	1.4216	9.26%
POD1 mouth opening change	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	6.6880	0.9064	7.3785	0.0000	4.9009	8.4752	95.31%
	Indirect effect	0.3290	0.5539			-0.7109	1.4505	4.69%
POD1 Landucci swelling scale change	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	5.8994	0.8040	7.3377	0.0000	4.3142	7.4846	84.07%
	Indirect effect	1.1177	0.5046			0.2368	2.1879	15.93%
POD3 VAS pain score	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	5.9452	0.7256	8.1939	0.0000	4.5146	7.3758	84.72%
	Indirect effect	1.0719	0.3873			0.3423	1.8653	15.28%
POD3 mouth opening change	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	6.0329	0.8442	7.1465	0.0000	4.3685	7.6973	85.97%
	Indirect effect	0.9842	0.5326			0.0069	2.0757	14.03%
POD3 Landucci swelling scale change	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	2.2979	0.9252	2.4838	0.0138	0.4738	4.1221	32.75%
	Indirect effect	4.7191	0.9878			2.9324	6.8092	67.25%
POD7 VAS pain score	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	6.3956	0.6839	9.3513	0.0000	5.0472	7.7441	91.14%

	Indirect effect	0.6214	0.3052			0.1596	1.3484	8.86%
POD7 mouth opening change	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	6.0545	0.7817	7.7450	0.0000	4.5132	7.5957	86.28%
	Indirect effect	0.9626	0.3052	0.6094		0.1496	2.5936	13.72%
POD7 Landucci swelling scale change	Total effect	7.0171	0.6926	10.1310	0.0000	5.6515	8.3827	100%
	Direct effect	5.1548	0.7217	7.1422	0.0000	3.7318	6.5778	73.46%
	Indirect effect	1.8623	0.3514	0.6094		1.1602	2.5665	26.54%

Note. X variable = Flap technique, Y variable = POD7 OHIP-14 total score, Covariate(s): All the population characteristics. POD:postoperative day.

Figures

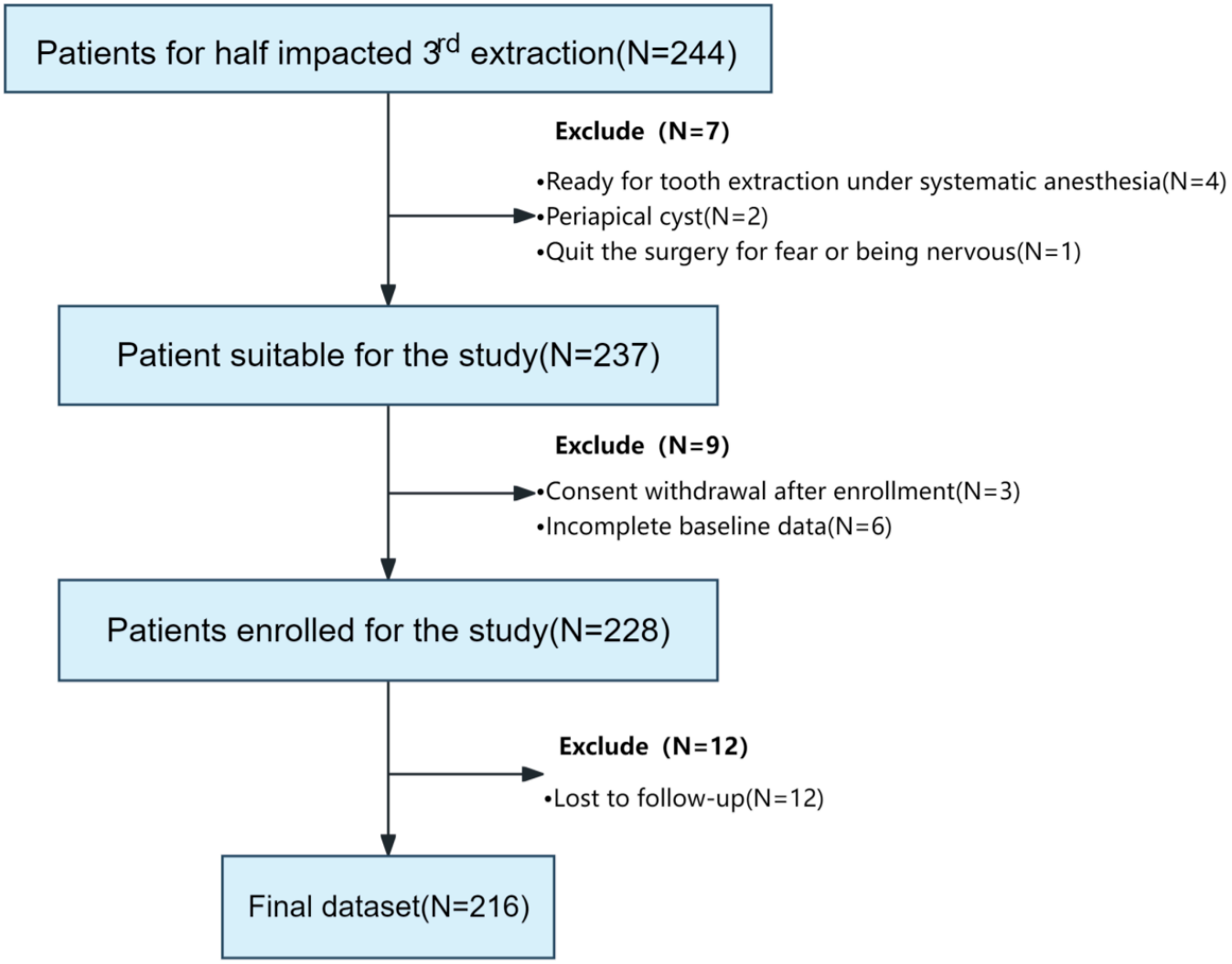


Figure 1

Flow Chart

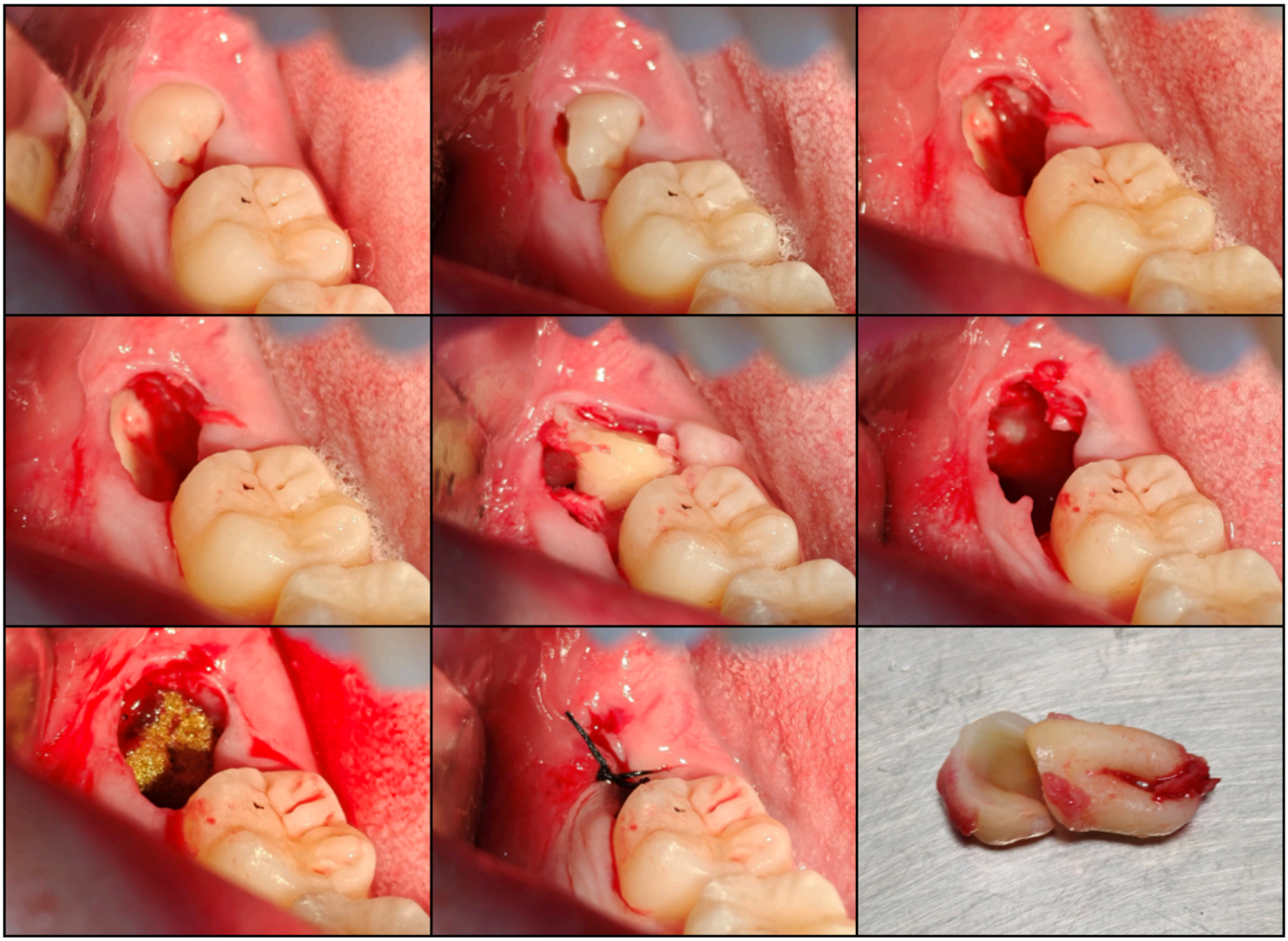


Figure 2

Intraoral photographs of flapless third molar extraction

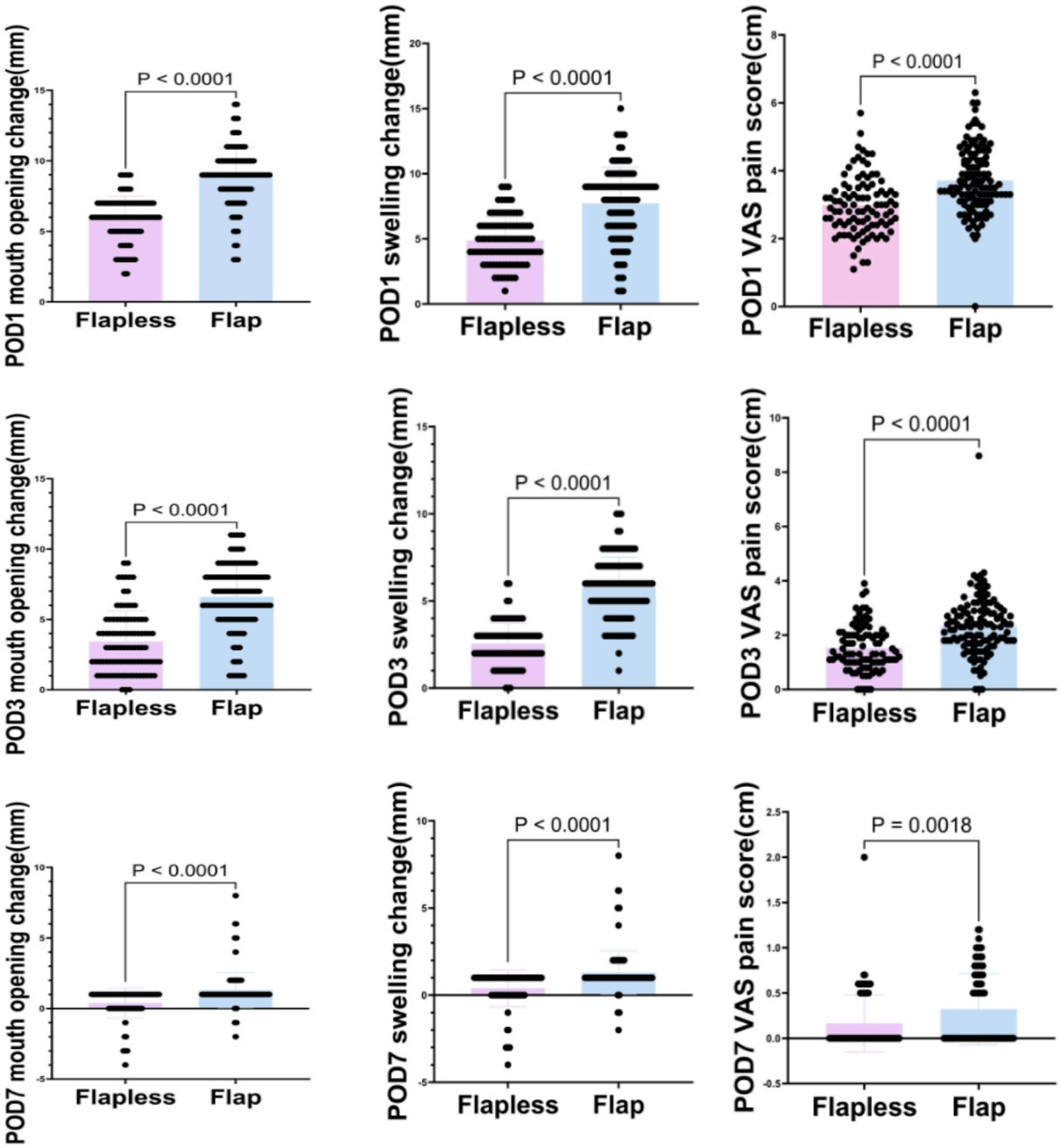


Figure 3

Scatter-column plot for the comparison of postoperative objective parameters between the two cohorts

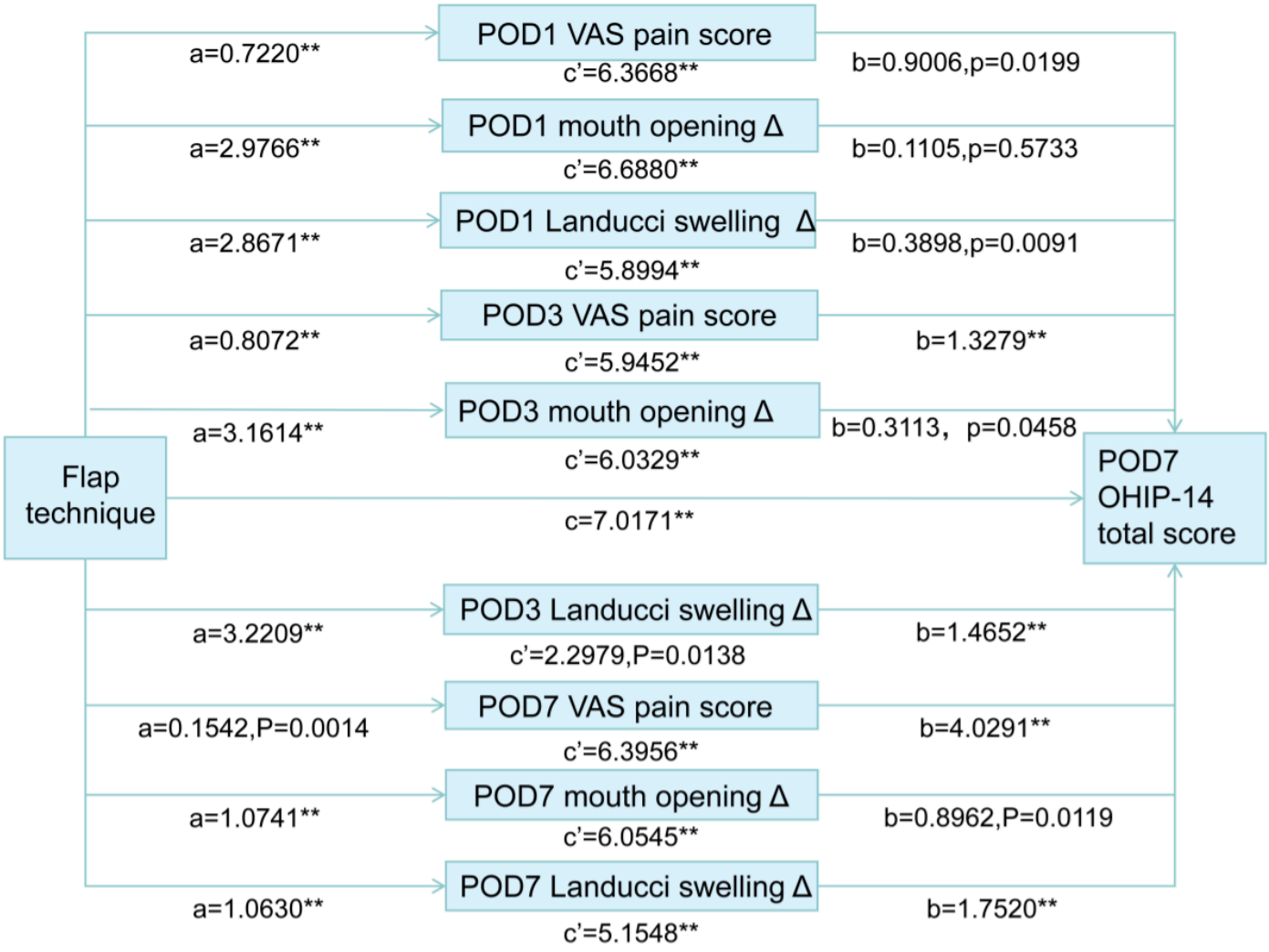


Figure 4

Mediating effect path diagram

Note. POD:postoperative day