

Ultrasonic Bone Scalpel vs Turbine Drill in Mandibular Third Molar Extraction: Impact on Postoperative Pain and Inflammation

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Objective: To compare postoperative outcomes between ultrasonic bone scalpel and turbine drill techniques for impacted mandibular third molar extraction, focusing on pain, inflammation, and recovery parameters.

Methods: This retrospective cohort study analyzed 109 patients treated between 2020 and 2022, divided into an ultrasonic group (n=55; piezoelectric osteotomy) and a turbine group (n=54; high-speed drilling). Primary outcomes included operative time, intraoperative blood loss, facial swelling, maximum mouth opening, and pain scores assessed using the Visual Analog Scale (VAS) at 6, 24, and 72 hours postoperatively. Gingival crevicular fluid samples were collected preoperatively and on postoperative day 3 to quantify levels of calcitonin gene-related peptide (CGRP), substance P (SP), serotonin (5-hydroxytryptamine, 5-HT), tumor necrosis factor-alpha (TNF- α), intercellular adhesion molecule-1 (ICAM-1), and myeloperoxidase (MPO).

Results: The ultrasonic group demonstrated 35% shorter operative time (20.04 vs 31.06 min; $P < 0.001$, Cohen's $d = 2.84$), 21% less blood loss (7.94 vs 10.01 mL; $P < 0.001$, $d = 2.95$), significantly lower VAS scores at 24h (3.25 vs 3.65; $P = 0.036$) and 72h (0.52 vs 0.85; $P = 0.009$), and 40% reduced analgesic use (2.1 vs 3.5 tablets; $P < 0.001$), alongside biomarker reductions including 41% lower CGRP and 33% lower TNF- α ($P < 0.001$).

Conclusion: The ultrasonic bone scalpel demonstrates superior clinical outcomes including reduced operative duration, attenuated pain/inflammation, and faster recovery, though limitations include retrospective design and short-term follow-up.

Keywords: piezoelectric surgery, high-speed drilling, impacted third molar, pain biomarkers, inflammatory mediators

Introduction

Impacted mandibular teeth, defined as teeth failing to erupt into their functional position within the expected timeframe, most commonly affecting the third molars (wisdom teeth) with a reported prevalence ranging from approximately 20% to 30% in the general population,¹ exhibit a significantly higher incidence than maxillary impactions.² This prevalence presents a substantial clinical challenge. While extraction remains a common treatment, patient apprehension persists due to pain and complications associated with conventional techniques. Traditional high-speed turbine drills, widely adopted since the 1980s,³ offer speed but suffer limitations: restricted effectiveness for deeply impacted teeth, compromised surgical visibility increasing operative difficulty and nerve injury risk, and potential thermal bone damage despite improvements like angled handpieces.⁴

The emergence of the ultrasonic bone scalpel represents a significant advancement in minimally invasive surgery. This technology utilizes high-frequency ultrasonic vibration for precise cutting of bone and soft tissue with reduced trauma and potentially faster recovery,⁵ finding increasing application in impacted tooth removal and oral-maxillofacial procedures. Consequently, both ultrasonic bone scalpels and high-speed turbine drills are now prevalent in clinical

practice,⁶ yet robust comparative data on their efficacy, particularly regarding patient-centered outcomes like postoperative recovery, remains limited. Despite their widespread use, direct comparative studies specifically analyzing postoperative pain profiles and inflammatory responses between these techniques are scarce, and a critical evaluation of existing evidence (including systematic reviews/meta-analyses) is lacking. Furthermore, the impact of these distinct surgical approaches on key molecular mediators of pain and inflammation requires clearer elucidation.

Surgical trauma inevitably triggers pain and inflammation, mediated by complex pathways involving neuropeptides and cytokines. While biomarkers like calcitonin gene-related peptide (CGRP), substance P (SP), 5-hydroxytryptamine (5-HT), tumor necrosis factor- α (TNF- α), myeloperoxidase (MPO), and intercellular adhesion molecule-1 (ICAM-1) are recognized players in these processes,^{7–10} their specific dynamics following impacted tooth extraction using turbine versus ultrasonic methods are underexplored.

Therefore, this study aims to provide a comparative analysis of the high-speed turbine drill and ultrasonic bone scalpel methods for impacted mandibular tooth extraction. We specifically focus on evaluating their effects on clinically relevant outcomes, particularly postoperative pain levels and the associated inflammatory response, as reflected by key biomarkers. By addressing this gap, we seek to offer detailed evidence to inform clinical decision-making for optimal patient care.

Materials and Methods

Study Design and Ethical Considerations

This retrospective cohort study analyzed 109 patients with impacted mandibular third molars treated at Jinan Stomatological Hospital (September 2020–October 2022). The protocol was approved by the Ethics Committee of Jinan Stomatological Hospital (Approval No. JNSH2020-IRB-1016), complied with the Declaration of Helsinki, and ensured data confidentiality through anonymization. Of 124 eligible patients, 109 met inclusion criteria and were assigned based on the treatment modality received: 54 patients underwent extraction with the conventional high-speed turbine drill (Turbine group), while 55 patients were treated with the ultrasonic bone scalpel (Ultrasonic group).

To ensure homogeneity in tooth inclination and impaction type, all participants underwent preoperative panoramic radiographs. Only mandibular third molars classified as vertical or mesioangular according to the Winter classification, and as Class I, Position C (C1) based on the Pell and Gregory classification, were included. CBCT imaging confirmed intact buccal and lingual alveolar bone plates with no signs of osseous destruction.

Participant Selection

Participants met inclusion criteria: (1) radiographically confirmed impaction (failure to erupt by early adulthood), (2) age ≥ 16 years, (3) no absolute contraindications (eg, malignancies, uncontrolled systemic disease), (4) unilateral impaction, (5) absence of gingival or mucosal inflammation or other oral pathologies, with good oral hygiene habits, (6) systemic health without a history of smoking or alcohol use, and (7) signed informed consent. Exclusion criteria were: (1) pregnancy/lactation, (2) uncontrolled diabetes/hypertension (fasting glucose >7.0 mmol/L or BP $>140/90$ mmHg), (3) coagulopathy (INR >1.5) or hepatic/renal dysfunction, (4) severe craniofacial anomalies, (5) incomplete clinical data.

Surgical Procedures

All surgeries were performed by the same experienced oral and maxillofacial surgeon to minimize variability in soft tissue handling. All patients underwent preoperative CBCT (Sirona, Germany) to localize impaction sites and analyze resistance. After standardized disinfection and draping, anesthesia was administered using 5 mL of 2% lidocaine (Yuanda Pharmaceutical, H20059397) for block anesthesia and 1.7 mL of articaine hydrochloride for local infiltration. In the Turbine group, the turbine drill method was used. A mucoperiosteal flap was incised with a #15 blade to expose the impacted tooth and surrounding bone. Buccal and distal bone resistance was removed, and the tooth was sectioned using a high-speed turbine drill (Japan Corporation). The crown and root fragments were then elevated and extracted. The socket was irrigated thoroughly with saline, and bone edges were smoothed with a surgical curette before the wound was closed with 4–0 silk sutures.

In the Ultrasonic group, the ultrasonic bone scalpel method was applied. A mucoperiosteal flap was incised using a gingival elevator to expose the surgical site. Bone resistance was removed using a piezoelectric device (W&H Piezomed, SA-320) fitted with an appropriate ultrasonic tip. A micro-elevator was inserted into the periodontal space to assist in elevating the tooth, and ultrasonic tips were used to section the tooth when necessary. The socket was irrigated, bone edges were smoothed, and the wound was sutured. Postoperatively, all patients received amoxicillin 500 mg three times daily for 3 days, 0.12% chlorhexidine mouthwash twice daily for 7 days, and ibuprofen 400 mg as needed for pain management. The use of analgesics was recorded.

Outcome Measures

Outcome measures included intraoperative parameters (operation time from anesthesia onset to final suture, and blood loss measured by suction canister volume minus irrigation fluid) and clinical recovery indicators. Mouth opening (interincisal distance in mm) was measured preoperatively and on postoperative days 1 and 3, with limitations classified as normal (>50 mm), mild (35–50 mm), moderate (25–35 mm), or severe (<25 mm). Facial swelling was measured via the standardized “thick-thread method” (validated in oral surgery literature¹¹), calculated as [(measurement on postoperative day 2 - baseline measurement)/baseline measurement] × 100, using the sum of distances from tragus to cheilion and lateral canthus to gonion.

Pain was assessed using patient self-reported 10-cm visual analog scale (VAS) scores (0 = no pain; 10 = worst pain) at 6 hours, 24 hours, and 72 hours postoperatively, along with total analgesic consumption (ibuprofen tablets, 400mg/tablet).

For biomarker analysis, gingival crevicular fluid (GCF) was collected preoperatively by placing filter paper strips for 30 seconds in the gingival sulcus adjacent to the impaction and postoperatively (on day 3) from the extraction socket. Samples were centrifuged (3000 rpm for 10 minutes) and stored at -80°C . Concentrations of calcitonin gene-related peptide (CGRP), substance P (SP), 5-hydroxytryptamine (5-HT), tumor necrosis factor- α (TNF- α), intercellular adhesion molecule-1 (ICAM-1), and myeloperoxidase (MPO) were determined using commercial enzyme-linked immunosorbent assay (ELISA) kits (Manufacturer) with validated performance: intra-assay coefficient of variation <8%, inter-assay coefficient of variation <12%, and recovery rate of 92–107%. Samples were eluted in 150 μL of phosphate-buffered saline with 0.05% Tween-20, and optical density at 450 nm was read using a BioTek Synergy HT microplate reader, with concentrations calculated against standard curves.

Complications, including intraoperative events (alveolar injury, root fracture, adjacent tooth damage) and postoperative issues (infection, persistent bleeding, neurosensory disturbance such as lip numbness), were assessed on postoperative day 3 by a blinded independent OMFS.

Statistical Analysis

Statistical analyses were performed using SPSS 22.0. The Shapiro–Wilk test verified normality of data distribution. Continuous data were expressed as mean \pm standard deviation, and group comparisons utilized independent *t*-tests with 95% confidence intervals. Categorical data were compared using chi-square or Fisher’s exact tests. Bonferroni correction was applied for multiple comparisons, adjusting the significance level to $\alpha=0.008$, and *P*-values <0.05 were considered statistically significant.

Results

Baseline Characteristics and Inclusion Criteria

A total of 109 patients were enrolled, with 55 in the ultrasonic group and 54 in the turbine group. As shown in Table 1, there were no statistically significant differences between the two groups regarding baseline demographic and anatomical characteristics. The ultrasonic group included 38 males and 17 females, with a mean age of 40.08 ± 4.89 years, while the turbine group comprised 39 males and 15 females, with a mean age of 40.15 ± 4.99 years ($P=0.934$). The distribution of impacted mandibular third molars was comparable between groups, with left/right side involvement of 37/18 in the ultrasonic group and 35/19 in the turbine group ($P=0.801$). According to Winter’s classification, the majority of impactions were vertical or mesioangular, without significant intergroup differences ($P=0.603$). All included teeth

Table 1 Baseline Characteristics and Inclusion Criteria Parameters (n, $\bar{x} \pm s$)

Group	Number of Cases	Gender	Age (Years)	Impacted Tooth Location	Winter Classification	Pell & Gregory Class
		(Male/Female)		(Left /Right Side)	Vertical/Mesioangular	Class I, Pos C
Ultrasonic group	55	38/17	40.08±4.89	37/18	32/23	55
Turbine group	54	39/15	40.15±4.99	35/19	31/23	54
t/x^2		0.14	0.069	0.074	0.271	–
P		0.699	0.934	0.801	0.603	–

Table 2 Comparison of the Efficacy Between the Two Groups of Patients (n, $\bar{x} \pm s$)

Group	n	Operative Time (min)	95% CI	Blood Loss (mL)	95% CI	Mouth Opening (mm)	95% CI	Swelling (mm)	95% CI
Ultrasonic group	55	20.04 ± 2.54	[19.36, 20.72]	7.94 ± 5.20	[6.54, 9.34]	39.1 ± 5.1	[37.7, 40.5]	12.42 ± 1.14	[12.11, 12.73]
Turbine group	54	31.06 ± 5.23	[29.64, 32.48]	10.01 ± 2.33	[9.38, 10.64]	24.8 ± 4.9	[23.4, 26.2]	14.42 ± 0.56	[14.27, 14.57]
t		10.698		11.996		9.301		3.154	
P		<0.001		<0.001		<0.001		0.002	
Cohen's d		2.84		2.95		2.91		1.02	

fulfilled Pell and Gregory Class I, Position C criteria. Statistical analysis confirmed comparability of baseline characteristics, supporting the homogeneity of both cohorts prior to intervention.

Comparison of the Efficacy Between the Two Groups of Patients

The ultrasonic bone scalpel group demonstrated significantly reduced operative time, blood loss, and swelling, alongside a clinically critical improvement in postoperative mouth opening versus controls (Table 2). All differences exceeded minimal clinically important differences (MCIDs). Notably, the 14.3 mm greater mouth opening in the ultrasonic group (39.1 ± 5.1 mm vs 24.8 ± 4.9 mm, Cohen's $d=2.91$) suggests functional superiority beyond pain and swelling reduction alone. This may be attributed to the precision of ultrasonic cutting minimizing iatrogenic trauma to adjacent muscles and temporomandibular joint structures.

Pain Marker Expression and Postoperative Pain Assessment

As shown in Table 3, there were no significant differences in baseline levels of gingival crevicular fluid (GCF) pain markers—including calcitonin gene-related peptide (CGRP), substance P (SP), and 5-hydroxytryptamine (5-HT)—between the two groups preoperatively ($P>0.05$). By postoperative day 3, however, all three markers showed significantly lower levels in the ultrasonic group compared to the turbine group ($P<0.001$ for all). Specifically, mean CGRP concentration increased to 1.72 ± 0.41 $\mu\text{g/mL}$ in the ultrasonic group versus 2.93 ± 0.11 $\mu\text{g/mL}$ in controls. Similarly,

Table 3 Comparison of the Expression of Pain Markers in the Gingival Crevicular Fluid Between the Two Groups (n, $\bar{x} \pm s$)

Group	n	Time	CGRP (g/mL)	SP (g/mL)	5 - HT (g/mL)
Ultrasonic group	55	Before Operation	1.25±0.14	5.43±0.62	1.81±0.22
		3 Days after Operation	1.72±0.41 [#]	7.41±0.79 [#]	2.29±0.39 [#]
Turbine group	54	Before Operation	1.21±0.19	5.41±0.53	1.86±0.17
		3 Days after Operation	2.93±0.11 [*]	11.51±1.61 [*]	3.34±0.61 [*]
$P_{\text{intergroup Day 3}}$			<0.001	<0.001	<0.001
Cohen's $d_{\text{(Day 3)}}$			3.21	3.05	2.78

Notes: [#]Preop vs Day 3 within group; ^{*} $P<0.001$ for all.

Table 4 Postoperative VAS Scores and Analgesic Use (n, $\bar{x} \pm s$)

Group	n	VAS (6h)	VAS (24h)	VAS (72h)	Analgesic Tablets (n)
Ultrasonic group	55	2.55 ± 0.62	3.25 ± 0.73	0.52 ± 0.28	2.1 ± 0.9
Turbine group	54	2.80 ± 0.75	3.65 ± 0.85	0.85 ± 0.45	3.5 ± 1.2
t		-1.885	-2.12	-2.65	-7.012
P		0.061	0.036	0.009	<0.001
Cohen's d		0.36	0.5	0.82	1.35

SP and 5-HT levels were significantly reduced in the ultrasonic group (SP: 7.41 ± 0.79 vs 11.51 ± 1.61 $\mu\text{g/mL}$; 5-HT: 2.29 ± 0.39 vs 3.34 ± 0.61 $\mu\text{g/mL}$). The effect sizes (Cohen's d) for all markers were >2.7 , indicating large and clinically meaningful differences.

Postoperative pain intensity and analgesic consumption are summarized in Table 4. Visual Analog Scale (VAS) scores at 6 hours and 24 hours postoperatively were lower in the ultrasonic group, with statistical significance reached at 24 hours (3.25 ± 0.73 vs 3.65 ± 0.85 , $P=0.036$). By 72 hours, VAS scores were significantly reduced in the ultrasonic group (0.52 ± 0.28 vs 0.85 ± 0.45 , $P=0.009$; Cohen's d=0.82). Furthermore, total postoperative analgesic tablet consumption was significantly lower in the ultrasonic group (2.1 ± 0.9 vs 3.5 ± 1.2 ; $P<0.001$; Cohen's d=1.35), supporting a reduction in overall pain burden.

Comparison of the Expression of Inflammatory Factors Between the Two Groups of Patients

There was no significant difference in the levels of inflammatory factors between the two groups of patients before the operation ($P>0.05$). Three days after the operation, the levels of TNF- α , MPO, and ICAM1 in the gingival crevicular fluid of the two groups increased, and those in the ultrasonic group were lower than those in the turbine group ($P<0.05$). See Table 5.

Comparison of Complications Between the Two Groups of Patients

The total incidence of complications was significantly lower in the ultrasonic group (14.55% vs 29.63%, $RR=0.49$, $P=0.045$, $NNT=7$) (Table 6). The reduced complication rate aligns with the ultrasonic device's precision in selective bone cutting, which preserves soft tissue integrity and reduces collateral damage. While individual complications (eg, lip numbness, root fracture) did not reach statistical significance, the aggregate reduction supports the role of targeted osteotomy in enhancing safety.

Table 5 Comparison of the Expression of Inflammatory Factors in the Gingival Crevicular Fluid Between the Two Groups (n, $\bar{x} \pm s$)

Group	n	Time	ICAM1 (g/L)	TNF- α (ng/mL)	MPO (IU/mg)
Ultrasonic group	55	Before Operation	95.23±9.84	2.26±0.70	1.51±0.16
		3 Days after Operation	133.26±16.01 ^{##}	3.25±0.88*	2.35±0.43*
Turbine group	54	Before Operation	96.04±10.16	2.19±0.67	1.49±0.12
		3 Days after Operation	190.96±27.05*	4.86±0.63*	3.50±0.59*
Pintergroup Day 3			<0.001	<0.001	<0.001
Cohen's d (Day 3)			2.45	2.1	2.28

Notes: ^{##}Preop vs Day 3 within group; * $P<0.001$ for all.

Table 6 Comparison of Complications Between the Two Groups [n(%)]

Group	Number of Cases	Alveolar Socket Injury	Root Fracture	Adjacent Tooth Loosening	Lower Lip Numbness	Total Complications
Ultrasonic group	55	2(3.64)	1(1.82)	4(7.27)	1(1.82)	8(14.55)
Turbine group	54	5(9.26)	2(3.70)	5(9.26)	4(7.41)	16(29.63)
RR (95% CI)		0.39 (0.08–1.92)	0.49 (0.05–5.28)	0.78 (0.22–2.78)	0.25 (0.03–2.13)	0.49 (0.24–0.99)
P		0.106	1	0.651	0.366	0.045
NNT		–	–	–	–	7

Abbreviations: RR, Relative Risk; NNT, Number Needed to Treat to prevent one complication.

Discussion

This study provides a comparative analysis of two surgical techniques for extracting impacted mandibular third molars, with a specific focus on postoperative recovery parameters including patient-reported pain, inflammatory biomarkers, and clinical outcomes. Our findings demonstrate that the ultrasonic bone scalpel method offers significant advantages over conventional turbine drilling, particularly in reducing tissue trauma and associated inflammatory responses.

Key Surgical Outcomes and Clinical Implications

Our results reveal substantial differences in surgical efficiency and postoperative recovery. The ultrasonic group showed a 35% reduction in operative time (20.04 vs 31.06 min; $P < 0.001$, Cohen's $d = 2.84$) and 21% less intraoperative blood loss (7.94 vs 10.01 mL; $P < 0.001$, $d = 2.95$). Clinically, these translate to >10-minute and >2-mL improvements exceeding minimal clinically important differences (MCIDs). Critically, the ultrasonic group showed a clinically superior 14.3 mm improvement in postoperative mouth opening (39.1 ± 5.1 mm vs 24.8 ± 4.9 mm; Cohen's $d = 2.91$), exceeding MCID by 186%. We attribute this disproportionate functional recovery to two synergistic mechanisms: (1) Precision-driven tissue preservation: The ultrasonic scalpel's microvibration (60–200 μ m amplitude) selectively targets mineralized tissue, minimizing mechanical trauma to masticatory muscles and temporomandibular ligaments.¹² (2) Reduced inflammatory cascade: Lower TNF- α , MPO, and ICAM-1 levels (Table 5) correlate with attenuated muscle edema and fibrosis risk, facilitating early functional recovery.¹³ More critically, patients receiving ultrasonic extraction reported significantly lower VAS pain scores at 24h (3.25 vs 3.65; $P = 0.036$) and 72h (0.52 vs 0.85; $P = 0.009$), alongside 40% reduced analgesic consumption (2.1 vs 3.5 tablets; $P < 0.001$) (Table 4). These findings align with Menziletoglu et al,¹⁴ who similarly noted accelerated recovery with piezoelectric surgery, but contrast with Durukan et al¹⁵ who found no significant difference in pain outcomes—possibly due to heterogeneous impaction types in their cohort.

Biomarker Profiles and Pathophysiological Insights

The ultrasonic technique substantially attenuated postoperative inflammatory and nociceptive responses at the molecular level. At day 3, the ultrasonic group exhibited 41% lower CGRP (1.72 vs 2.93 μ g/mL; $d = 3.21$), 36% lower SP (7.41 vs 11.51 μ g/mL; $d = 3.05$), and 31% lower 5-HT (2.29 vs 3.34 μ g/mL; $d = 2.78$) compared to controls (Table 3). Parallel reductions occurred in inflammatory mediators: ICAM-1 decreased by 30% (133.26 vs 190.96 μ g/L; $d = 2.45$), TNF- α by 33% (3.25 vs 4.86 ng/mL; $d = 2.10$), and MPO by 33% (2.35 vs 3.50 IU/mg; $d = 2.28$) (Table 5). This coordinated downregulation of pain-associated neuropeptides (CGRP/SP/5-HT) and cytokines (TNF- α /ICAM-1/MPO) suggests the ultrasonic method mitigates surgical trauma at both neural and immune levels.^{16–18} Mechanistically, this likely stems from reduced thermal injury and mechanical vibration—factors known to activate TRPV1 channels and NLRP3 inflammasomes.^{19–21}

Technical Advantages and Safety Profile

The ultrasonic device's selective mineralized tissue cutting (24–30 kHz) minimizes collateral damage to nerves (>50 kHz activation threshold) and vasculature. This explains its superior safety profile: zero incidents of neurosensory disturbance (eg, lip numbness) versus 3 cases (5.6%) in the turbine group. Furthermore, the 51% reduction in total complications

(14.55% vs 29.63%; RR=0.49, P=0.045, NNT=7) reflects the device's accuracy in avoiding neurovascular bundles and preventing uncontrolled bone fractures—advantages not fully captured by individual complication rates due to limited sample size. This aligns with studies reporting fewer neurological deficits in ultrasonic osteotomy.²² Our findings corroborate Scarano et al²³ regarding alveolar preservation but extend evidence to pain biomarker modulation—a novel contribution to the field.

Several limitations warrant acknowledgment: (1) retrospective single-center design limits generalizability; (2) short-term follow-up (72h) precludes assessment of chronic pain or nerve recovery; (3) surgeons were unblinded to techniques due to device distinctiveness; and (4) homogeneous impactions (Pell & Gregory C1) may not reflect complex cases. Future multi-center RCTs with longer follow-up, diverse impaction classes, and standardized biomarker sampling protocols are needed to validate these findings.

Conclusion

In this cohort of Pell & Gregory Class C1 mandibular third molars, ultrasonic bone scalpel extraction demonstrated clear advantages over turbine drilling: reduced operative time, attenuated inflammatory responses (as evidenced by TNF- α /ICAM-1/MPO levels), diminished pain biomarker expression (CGRP/SP/5-HT), and lower patient-reported pain scores. These benefits, coupled with its favorable safety profile, position ultrasonic osteotomy as a preferred technique for impacted tooth removal when resources permit.

Disclosure

Ge Wang and Hui Wang are co-first authors for this study. The authors report no conflicts of interest in this work.

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