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Randomized clinical study comparing Piezoelectric Surgery with conventional rotatory osteotomy in mandibular third molars surgeries

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PoSSe scale

Abstract *Purpose:* The aim of this study was to evaluate the performance and to assess the post-operative sequel and quality of life after removal of impacted mandibular third molars using piezoelectric surgery compared with conventional rotatory osteotomy.

Patients and methods: A single blinded, randomized, control clinical study was performed. Sixty-three patients (44 males, 19 females) who presented with bilaterally asymptomatic impacted mandibular third molars were included in this analysis. Each patient was treated, at two separate sessions approximately 4 weeks apart, with a conventional rotatory hand piece on one side of the mandible and a piezoelectric device on the contralateral side. Patients were followed up on post-operative days 1, 3, 5, 7, and 15 to rate the pain, swelling and trismus. Inferior alveolar nerve paresthesia was evaluated up to 12 months postoperatively.

Results: The severity of the pain, trismus and swelling using the piezosurgery were significantly different from the rotary group. In both groups, pain was most intense and peaked during the first post-operative day, while swelling and trismus reached peak levels on the third postoperative day. The piezoelectric procedure resulted in a significantly longer procedural duration compared to the rotatory surgery ($P < 0.001$).

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Conclusion: Piezoelectric surgery is considered a viable alternative technique compared to the conventional rotary systems and can improve a patient's quality of life. Thus, piezoelectric surgery might be a preferred modality for patients undergoing complicated surgical extraction of impacted lower third molars.

1. Introduction

Surgical extraction of the lower third molars is the most common surgical procedure in the oral surgery field (Graziani et al., 2006). As anticipated with any surgical intervention, there are several intra- and post-operative complications that could significantly affect post-surgical sequelae, as well as biological and social outcomes (Kim et al., 2006). The most common postoperative signs and symptoms of complications are pain, swelling and trismus (Ruta et al., 2000), all of which can be affected by varying degrees of severity of other factors (Bello et al., 2011; Bouloux et al., 2007).

Various methods over recent years have been suggested and utilized to minimize post-operative sequelae, such as platelet-rich fibrin administration (Gülşen and Şentürk, 2017), laser application (Kahraman et al., 2017), cryotherapy (Zandi et al., 2016), drug injections (Gorecki et al., 2017), and various flap designs (Ottria et al., 2017). However, one of the most important methods has involved the use of osteotomy techniques to minimize trauma and the generation of heat associated with cutting the bone or osteotomy during surgical extraction of the lower third molars (Al-Delayme, 2013). Hence, it is beneficial to choose the most optimal technique for removal of the lower third molars in order to avoid jeopardizing the adjacent bone, teeth and the surrounding soft tissues (Bhati et al., 2017).

The most commonly used instrument for impacted tooth removal is the rotary hand piece. However, clinicians may find that this method leaves irregular surfaces in the bone and marginal osteonecrosis. It also impairs healing due to overheating of bone and damage to adjacent tissues (Maurer et al., 2007; Rullo et al., 2013). Piezoelectric surgery is a novel osteotomy technique that utilizes micro-vibrations of scalpels at ultrasonic frequency. Piezoelectric surgery has been proposed as an alternative for removing third molar surgery with the conventional rotating bone cutting instruments (Bartuli et al., 2013; Ruga et al., 2011; Sortino et al., 2008).

Piezoelectric surgery is a pioneering technique that has an added advantage over burs and micro saws. The ultrasonic vibrations break down irrigation liquid into very small particles that are washed out from the operating field therefore, allowing for clear, unobstructed vision (Arakji et al., 2016). Its mechanism of action is based on the ability of certain ceramics and crystals to deform when an electric current is passed across them, resulting in a microvibration amplitude between 60 and 200 mm/s at a modulated ultrasonic frequency of 24–29 kHz resulting in a clean, precise osteotomy (Vercellotti, 2004).

Numerous studies have compared the duration of operation and patient discomfort using both piezoelectric surgery and rotary instruments. However, these factors have not been assessed in complicated cases and osteotomy methods. This study aims to test the hypothesis that piezoelectric ultrasonic surgical systems are less invasive compared to conventional rotary hand piece tools for surgical extraction of impacted lower third molars.

This study has been conducted as a randomized, split-mouth to compare the impact of piezoelectric surgery on the patient subjective experience after surgical extractions requiring bone osteotomy alone and bone osteotomy combined with tooth splitting.

2. Material and methods

2.1. Study design

This is a prospective, single blinded, randomized clinical study. The study was conducted from June 2012 through April 2015 and approved by the local ethics committee according the Declaration of Helsinki guidelines. Seventy-one patients (49 males, 23 females) of the age range (17.5–29 years) were selected for removal of bilaterally impacted mandibular third molars.

We obtained a written consent from all patients prior to the start of the study explaining the surgical procedure and possible complications. The study was performed using the "split-mouth method" to remove compliance bias. This is where one side of the mouth was assigned for surgical removal of the impacted mandibular third molar using the conventional rotary hand piece (control group), and the contralateral side of the mouth was assigned for surgical removal of impacted mandibular third molar using a piezoelectric powerful ultrasonic surgical system with an LED (study group). Patients were sequentially numbered from 1 to 71. The treatment modality (rotary vs. piezoelectric) and the side to be operated on (right vs. left) were determined by tossing a coin, where 'face' was the test site and 'back' was the control side.

Patients were excluded from the study if they had systemic diseases or a clinically significant medical history, regularly used medications with possible anti-inflammatory activity (eg, antihistamines), and had a history of allergy. We also excluded pregnant or breast-feeding women and heavy tobacco smokers (> 10 cigarettes daily) from the study. The impacted third molar had to be in the same angulation and spatial relations (Alvira-González et al., 2017), as well as the same difficulty index bilaterally as described by Pederson (Yuasa et al., 2002).

2.2. Surgical procedure

To rule out operator bias, all surgeries were performed by an experienced oral and maxillofacial surgeon according to a standardized technique of wisdom tooth extraction (Baqain et al., 2002). The two extractions were performed in two separate sessions approximately 4 weeks apart to allow for total recovery after the initial extraction. The treatment modality (rotary vs. piezoelectric) sequence was randomly assigned. During the surgical procedure, all other variables were constant, including the local anesthesia, incision design and the suturing technique.

In the control group, bone osteotomy and tooth splitting were done by NSK SGS-ES 1:1 surgical straight hand piece. In the contralateral study group, bone osteotomy was done using the piezoelectric VarioSurg LED with TiN (Titanium Nitride) coated bone cutting tips (model: SG1) set at 0.6 mm thickness. Tooth splitting was done using coated cutting tips (model SG17) set at 0.7 mm thickness according to the manufacturer's instructions.

2.3. Pre and post-operative variables and their evaluation

All evaluations and measurements were done pre-operatively and on the post-operative days 1, 3, 5, 7 and 15. Swelling, pain, and maximum inter-incisal opening of the mouth were assessed. The subjective experience of patient satisfaction was evaluated immediately after the procedure, and the PoSSe scale to evaluate each patient 1 week after surgery was used.

Postoperatively, all patients received the same medications consisting of amoxicillin (500 mg) three times daily for 5 days, ibuprofen (400 mg) three times daily for three days, and 0.2% chlorhexidine gluconate mouthwash three times daily for 7 days. Patients were follow-up on post-operative days 1, 3, 5, 7 and 15.

2.4. Outcome variables

The subjective experience of each patient was assessed using a questionnaire regarding their satisfaction about the surgical procedure and noise disturbance from the surgical device. These were assessed using a graded scale of very satisfied, fairly satisfied, fairly unsatisfied, and very unsatisfied.

The assessments were conducted by a single blind operator who was not the surgeon who performed the procedures. Each measurement was repeated three times on each patient before and after the operation. The average measurements were then taken and recorded.

Pain was assessed by a 10 mm visual analogue scale (VAS), with the end points marked as ''no pain'' and ''worst pain ever experienced''. Absence of pain was scored as 0. If pain was present, the patient was asked to select a field from 1 to 10. For each patient, the appropriate score was recorded in the questionnaire by one operator.

To measure facial swelling, two distances were recorded: the distance from the corner of the mouth to the ear lobe and the outer canthus of the eye, to the angle of the mandible measured by a thread which was then transferred to a ruler. The preoperative measurement was the baseline value. The difference between the postoperative and preoperative measurements were calculated to measure the swelling area in (cm^2).

Trismus was assessed by measuring the differences in mouth opening (inter-incisal distance preoperatively and postoperatively). The preoperative measurement was the baseline value. The difference between the postoperative and preoperative measurements was calculated to measure the trismus (mm).

Paresthesia of the inferior alveolar nerve was defined as any postoperative change in sensitivity of the tissues innervated by the mandibular branch of trigeminal nerve (evaluated both subjectively and objectively by light touch (cotton wisp) and two-point discrimination methods) (Jerjes et al., 2010). Patients with altered sensation were followed weekly for 1–12 months.

The PoSSe score (Ruta et al., 2000) is derived from the PoSSe scale by adding the responses to each of the individual questions. The PoSSe scale was designed to assess a patient's perception of postoperative adverse effects in 7 subscales: eating, speech, sensation, appearance, pain, sickness, and interference with daily activities. The PoSSe scale was administered to each patient 1 week after surgery.

2.5. Statistics data analysis

The data obtained from the control and experimental groups were tabulated and recorded into a Microsoft Office Excel spreadsheet and then compared by statistical analyses. Clinical quantitative variables were analyzed using paired ??-test, and qualitative data were analyzed using Fischer's exact test. A value of $p \leq 0.05$ was taken to indicate statistical significance; SPSS 16 for Windows (SPSS, Inc, Chicago, IL) was used for statistical analysis.

3. Results

Eight of the 71 patients were excluded from the study for failure to follow-up within an appropriate period following surgery. The final 63 patients (44 males, 19 females) were included in the statistical analysis (Table 1).

All impacted mandibular third molars were successfully removed; thus, the operative success rate was 100%. All patients were thoroughly, clinically evaluated starting from the first postoperative day until postoperative day 14. All patients showed uneventful soft tissue healing with absence of infection; there were no cases of infection in either group.

With regards to the Pell and Gregory classification, there were high scores (levels) but we did not include these in the final result because it was statistically difficult to examine the significance with the low number of cases. Therefore, the data was not adjusted in the final analysis tables. Winter's Classification, number of roots, and duration of operation showed statistically significantly less score in the piezoelectric surgery group compared to the rotary group on follow-up days1, 3, 5, 7 and 15 (Table 2).

The results in Table 3 indicate that the piezoelectric surgery positively affected pain, swelling and trismus postoperative clinical sequelae of mandibular third molar tooth removal. The data from the self-reported questionnaires shown in Tables 3 and 4 demonstrates that the subjective experience of patient satisfaction regarding the surgical procedure and disturbance related to noise from the surgical device, PoSSe scale when the difficulties of surgical procedures increase.

Table 4 reveals the statistical analysis of the mean pain, swelling and trismus measured in both groups, in addition to the patient subjective experience and PoSSe scale. Significant differences were observed at postoperative days 1, 3, 5, 7 and 15 days between mean measurements in all cases that under-

Table 1 Demographic data distributions of patients according to gender, age, winter's, Pell and Gregory classification, difficulty index of Pederson, number of roots and indication for removal (n = 63).

Variables	Control	
	N	%
Gender		
M	44	69.84
F	19	30.15
Age (years)		
Mean	21.46 ± 3.71	
Range	17.5–29	
Winter's classification		
Mesioangular	26	41.26
Vertical	20	31.74
Horizontal	11	17.46
Distoangular	6	9.52
Pell and Gregory classification		
IA	17	26.98
IB	8	12.69
IC	6	9.52
IIA	14	22.22
IIB	6	9.52
IIC	6	9.52
IIIA	3	4.76
IIIB	2	3.17
IIIC	1	1.58
Difficulty index of Pederson		
Simple	26	41.26
Moderate	22	34.92
Difficult	15	23.80
No. of roots		
Multiple	22	34.92
Singular	41	56.-7
Indication for removal		
Prophylactic removal	24	38.09
Orthodontic reason	39	61.90

Abbreviations: N, Number; %, percentage.

went piezoelectric surgery as compared to rotary surgery, especially in all cases that required bone osteotomy with tooth sectioning.

In both groups, pain was reported to be most intense and peaked by postoperative day 1, while postoperative swelling and trismus peaked by postoperative day 3. By postoperative day 14, most patients had restored their preoperative values in both groups (Tables 2–4).

According to our findings, the piezoelectric had a longer duration compared to the rotary surgery and the difference was statistically significant for all postoperative variable outcomes, especially when the surgical procedure took > 30 min (Tables 2–4).

The related variables according to presence of inferior alveolar nerve paresthesia and recovery after surgery in both groups presented in Table 5. Paresthesia during rotary surgery was reported by three patients (4.76%), two of these patients needed more than six months to be symptom-free compared to one patient (1.58%) who recovered in less than one postoperative month. All patients had temporary paresthesia; none had permanent paresthesia or anesthesia. All cases were unilateral.

4. Discussion

Surgical extraction of lower third molars can be challenging. As clinicians it is our priority to aid optimal therapeutic outcomes while preserving the integrity and viability of the surrounding anatomical structures. It is this balance of trauma and healing that initiated ongoing efforts to utilize piezoelectric surgery, which is now considered a novel technique with promising results.

There is a great deal of literature (Arakji et al., 2016; Badenoch et al., 2016; Bartuli et al., 2013; Bhati et al., 2010; Bhati et al., 2017; Mantovani et al., 2013; Mistry et al., 2016; Sortino et al., 2008) on the relationships between the postoperative complications following extraction of the lower third molars using piezoelectric surgery. However, little has been published (Basheer et al., 2017; Chang et al., 2015; Goyal et al., 2012; Piersanti et al., 2014) regarding patient perceptions on postoperative quality of life. Moreover, most of these studies have evaluated postoperative complications associated with the rotary systems in general and in an isolated manner without adjusting for potential intra-individual anatomic and operative-specific risk indicators.

The results of the study confirmed our overall hypothesis. The piezoelectric study group showed statistically relevant decreases in the incidence and severity of postoperative pain, swelling, trismus, and nerve paresthesia. Furthermore, patients had remarkably better postoperative perceptions of quality of life.

The following describes the outcomes of the study and how piezoelectric surgery influences postoperative outcomes based on patient anatomic, radiographic and operative-specific indicators after third molar surgery compared to the rotary systems.

Previous studies have shown that the surgical outcome (pain, swelling and trismus) following lower third molar removal are influenced by various factors, such as angulations of impaction, especially distoangular impaction, bone removal combined with tooth sectioning, difficulty of the surgical procedure, and operation duration (Al-Delayme, 2013; Baqain et al., 2012; Bartuli et al., 2013; Graziani et al., 2006; Jerjes et al., 2006).

A thorough understanding of these risk factors is important as it facilitates proper management. Our study showed that piezoelectric surgical removal of the lower third molars significantly reduced risk factors of morbidity. We also report a statistically significant decrease in the intensity of post-operative mean recorded VAS score for pain, which parallels results obtained by Arakji et al. (2016), Basheer et al. (2017), Goyal et al. (2012), Mantovani et al. (2014), Piersanti et al. (2014).

In patients that had piezosurgery, a lower VAS pain score was reported following bone removal and tooth sectioning in moderate and very difficult cases during lower third molar surgery. This finding is likely attributed to the fact that piezosurgery is minimally invasive and is optimal for protecting the surrounding soft tissues and important structures, such as nerves, vessels, mucosa, and bone (Gülnahar et al., 2013;

Table 2 Comparison of pain, swelling and trismus in Winter's classification, number of roots and duration of operation in rotary vs piezoelectric surgery procedures at different follow-up periods.

			Pain(mm) mean ± SD			Swelling (Cm) mean ± SD			Trismus (mm) mean ± SD		
			Control group	Study group	P	Control group	Study group	P	Control group	Study group	P
Winter's classification	Mesioangular	Base line	000	000	NA	10.05 ± 0.63	10.17 ± 0.81	0.43	45.17 ± 2.38	45.17 ± 2.38	NA
		Day 1	3.37 ± 2.16	2.05 ± 2.04	0.109	11.23 ± 1.36	10.53 ± 0.73	0.37	36.38 ± 3.21	43.11 ± 2.13	0.43
		Day 3	2.19 ± 1.43	1.28 ± 1.13	0.034*	13.32 ± 1.47	11.68 ± 1.17	0.065*	31.44 ± 4.72	40.68 ± 4.09	0.018*
		Day 5	1.45 ± 1.01	0.96 ± 0.84	0.068*	12.26 ± 1.73	11.00 ± 0.72	0.001†	38.74 ± 3.56	43.75 ± 2.08	0.001†
		Day 7	1.02 ± 0.55	0.18 ± 0.22	0.001†	10.38 ± 0.81	10.19 ± 0.67	0.001†	39.86 ± 3.17	44.10 ± 1.14	0.001†
		Day 14	000	000	NA	10.12 ± 0.83	10.16 ± 0.83	0.82	45.12 ± 1.28	45.16 ± 0.09	0.001†
	Vertical	Base line	000	000	NA	10.11 ± 0.82	10.29 ± 0.93	0.43	45.14 ± 2.62	45.14 ± 2.62	NA
		Day 1	3.98 ± 2.91	2.74 ± 2.35	0,180	11.84 ± 1.42	11.14 ± 0.81	0.86	33.78 ± 3.68	40.29 ± 2.88	0.038*
		Day 3	3.17 ± 1.85	2.04 ± 1.69	0,068*	13.93 ± 1.47	12.42 ± 1.30	0.05*	28.65 ± 5.79	37.99 ± 4.56	0.001†
		Day 5	2.35 ± 2.11	1.08 ± 01.27	0.001†	12.87 ± 1.84	11.46 ± 0.83	0.001†	36.09 ± 3.62	42.81 ± 2.39	0.000‡
		Day 7	1.18 ± 0.94	0.48 ± 0.2458	0.001†	10.96 ± 0.72	10.54 ± 0.34	0.001†	40.04 ± 3.39	44.35 ± 2.17	0.001†
		Day 14	0.38 ± 0.16	000	0.001†	10.28 ± 0.58	10.31 ± 0.06	0.041*	44.31 ± 1.81	45.07 ± 2.26	0.033*
	Horizontal	Base line	000	000	NA	10. 08 ± 0.77	10.05 ± 0.69	0.89	45.23 ± 2.16	45.23 ± 2.16	NA
		Day 1	5.24 ± 3.17	3.52 ± 3.11	0.001†	12.09 ± 1.26	11.17 ± 1.48	0.013*	32.89 ± 4.39	39.87 ± 3.42	0.000‡
		Day 3	3.75 ± 2.45	2.40 ± 2.73	0.001†	14.37 ± 1.72	12.26 ± 1.44	0.001†	28.83 ± 6.47	37.75 ± 4.39	0.000‡
		Day 5	2.07 ± 2.16	1.42 ± 1.33	0.001†	13.19 ± 1.17	11.96 ± 1.27	0.000‡	35.76 ± 3.63	41.89 ± 3.25	0.000‡
		Day 7	1.23 ± 1.48	0.91 ± 0.54	0.000‡	11.17 ± 1.65	10.83 ± 0.79	0.000‡	39.23 ± 3.18	43.46 ± 2.72	0.001†
		Day 14	0.16 ± 0.07	000	0.000‡	10.96 ± 1.32	10.30 ± 0.47	0.001†	43.49 ± 2.05	44.97 ± 2.12	0.001†
	Distoangular	Base line	000	000	NA	10.17 ± 0.83	10.21 ± 0.75	0.89	45.21 ± 2.0.8	45.21 ± 2.0.8	NA
		Day 1	6.40 ± 3.15	4.38 ± 3.24	0.000‡	12.37 ± 2.17	11.41 ± 1.79	0.001†	31.89 ± 4.46	39.84 ± 3.26	0.000‡
		Day 3	4.79 ± 2.69	2.81 ± 2.64	0.000‡	14.85 ± 2.09	12.65 ± 1.58	0.000‡	27.92 ± 6.26	37.11 ± 4.59	0.000‡
		Day 5	3.11 ± 2.38	1.62 ± 1.85	0.000‡	14.07 ± 1.82	11.87 ± 1.21	0.000‡	35.01 ± 3.77	41.82 ± 3.12	0.000‡
		Day 7	1.73 ± 1.67	1.14 ± 0.72	0.000‡	11.12 ± 1.14	10.17 ± 0.76	0.000‡	38.39 ± 3.35	43.22 ± 2.73	0.000‡
		Day 14	0.28 ± 0.12	000	0.000‡	10.96 ± 1.17	10.38 ± 0.46	0.000‡	43.27 ± 2.42	44.98 ± 2.36	0.000‡
Numbers of roots	Singular	Base line	000	000	NA	10.15 ± 0.53	10.16 ± 0.62	0.41	45.24 ± 2.15	45.24 ± 2.15	NA
		Day 1	4.43 ± 1.83	2.31 ± 1.54	0.231	11.62 ± 1.10	10.67 ± 0.81	0.73	36.74 ± 3.24	43.16 ± 2.19	0.85
		Day 3	2.15 ± 1.26	1.78 ± 1.28	0.094*	13.39 ± 1.67	11.79 ± 0.98	0.06*	31.49 ± 4.81	40.78 ± 4.16	0.011*
		Day 5	1.37 ± 1.05	0.92 ± 1.06	0,075*	12.41 ± 1.74	10.93 ± 0.77	0.001†	38.82 ± 3.32	43.82 ± 2.13	0.001†
		Day 7	1.08 ± 0.64	0.43 ± 0.13	0.001†	10.59 ± 0.88	10.14 ± 0.65	0.46	39.92 ± 3.17	44.11 ± 1.18	0.001†
		Day 14	0.34 ± 0.17	000	0.000‡	10.17 ± 0.83	10.14 ± 0.89	0.44	45.20 ± 0.48	45.22 ± 0.14	0.96
	Multiple	Base line	000	000	NA	10. 11 ± 0.69	10.08 ± 0.63	0.11	45.18 ± 2.41	45.18 ± 2.41	NA
		Day 1	5.43 ± 2.11	3.01 ± 1.82	0.001†	11.87 ± 1.03	10.97 ± 1.25	0.04*	32.96 ± 4.26	39.81 ± 3.37	0.000‡
		Day 3	4.62 ± 1.68	1.73 ± 1.74	0.001†	12.25 ± 1.49	10.03 ± 1.44	0.000‡	28.75 ± 6.33	37.92 ± 4.18	0.000‡
		Day 5	2.26 ± 1.23	1.39 ± 1.09	0.000‡	11.17 ± 1.17	10.86 ± 1.27	0.01*	35.91 ± 3.05	41.94 ± 3.18	0.000‡
		Day 7	1.05 ± 0.45	0.73 ± 0.04	0.000‡	10.88 ± 1.45	10.51 ± 0.39	0.03*	39.64 ± 3.28	43.53 ± 2.38	0.001†
		Day 14	0.41 ± 0.34	000	0.000‡	10.56 ± 1.02	10.17 ± 0.06	0.001†	43.25 ± 1.77	44.96 ± 1.07	0.001†
Duration time (min)*Control group (19 ± 4.73) study group (23 ± 5.82)*	≤10	Base line	000	000	NA	10.12 ± 0.45	10.14 ± 0.37	0.22	45.27 ± 2.29	45.27 ± 2.29	NA
		Day 1	3.32 ± 2.04	2.12 ± 2.08	0.362	10.76 ± 1.21	10.42 ± 0.25	0.54	36.49 ± 3.18	43.13 ± 2.11	0.63
		Day 3	2.02 ± 1.57	1.09 ± 0.84	0.034*	12.64 ± 1.16	11.07 ± 0.94	0.05*	31.52 ± 4.83	40.92 ± 4.13	0.061*
		Day 5	0.85 ± 0.43	0.21 ± 0.37	0.001†	11.83 ± 1.35	10.79 ± 0.58	0.72	38.98 ± 3.72	43.88 ± 2.07	0.001†
		Day 7	00	00	NA	10.26 ± 0.14	10.23 ± 0.09	0.65	40.08 ± 3.14	44.23 ± 1.12	0.001†
		Day 14	00	00	NA	10.12 ± 0.45	10.14 ± 0.37	0.22	45.14 ± 1.09	45.25 ± 0.24	0.29

(*continued on next page*)

Table 2 (*continued*)

		Pain(mm) mean ± SD			Swelling (Cm) mean ± SD			Trismus (mm) mean ± SD		
		Control group	Study group	P	Control group	Study group	P	Control group	Study group	P
11–20	Base line	000	000	NA	10.21 ± 0.84	10.19 ± 0.79	0.76	45.16 ± 2.47	45.16 ± 2.47	NA
	Day 1	4.81 ± 2.74	3.29 ± 2.44	0.001†	11.71 ± 1.12	10.67 ± 1.03	0.03*	34.78 ± 3.38	40.87 ± 2.37	0.041*
	Day 3	3.72 ± 1.67	2.14 ± 1.85	0.001†	13.40 ± 1.68	11.77 ± 1.12	0.000‡	29.82 ± 5.49	38.11 ± 4.27	0.000‡
	Day 5	2.39 ± 2.21	1.47 ± 01.38	0.001†	12.26 ± 0.92	11.04 ± 0.83	0.001†	36.61 ± 3.87	43.11 ± 2.09	0.000‡
	Day 7	1.27 ± 1.18	0.83 ± 0.42	0.001†	11.39 ± 0.78	10.52 ± 0.41	0.79	40.07 ± 3.13	44.21 ± 2.22	0.001†
	Day 14	0.32 ± 0.09	000	0.000‡	10.34 ± 0.47	10.21 ± 0.11	0.26	44.03 ± 1.85	45.11 ± 2.49	0.001†
> 30	Base line	000	000	NA	10.28 ± 0.84	10.31 ± 0.79	0.96	45.19 ± 2.41	45.19 ± 2.41	NA
	Day 1	6.27 ± 3.37	4.28 ± 3.19	0.000‡	12.41 ± 2.13	11.25 ± 1.41	0.000‡	32.18 ± 4.26	39.75 ± 3.63	0.000‡
	Day 3	4.74 ± 2.47	2.77 ± 2.58	0.000‡	14.81 ± 2.15	12.49 ± 1.61	0.000‡	29.38 ± 6.36	37.21 ± 4.62	0.000‡
	Day 5	3.09 ± 2.44	1.77 ± 1.76	0.000‡	13.92 ± 2.48	11.82 ± 1.42	0.000‡	35.83 ± 3.81	42.09 ± 2.93	0.000‡
	Day 7	1.88 ± 1.69	1.06 ± 0.49	0.000‡	11.97 ± 1.53	10.52 ± 0.93	0.000‡	38.84 ± 3.42	43.85 ± 2.91	0.000‡
	Day 14	0.14 ± 0.11	000	0.000‡	10.88 ± 0.79	10.41 ± 0.65	0.001†	43.05 ± 2.13	44.93 ± 1.18	0.000‡

Abbreviations: Min, Minutes; mm, Millimeter; Cm, Centimeters; SD, Standard Deviation; NS, Non-significant; *P < 0.05; †P < 0.01; ‡P < 0.001.

Labanca et al., 2008; Mantovani et al., 2014, Piersanti et al., 2014).

The rotary procedure showed a greater clinical value of facial swelling compared to the piezoelectric surgery in all the postoperative times, especially at postoperative day 3, which is in agreement with others (Jiang et al., 2015; Mantovani et al., 2013; Mistry et al., 2016; Sortino et al., 2008; Troedhan et al., 2011).

Minimal surface area is affected when using piezoelectric surgery (Goyal et al., 2012); this factor may contribute to the statistically significant results obtained showing a greater decrease of swelling and trismus in a high risk cases like distoangular, vertical type of impaction, and an increase in the degree of difficulty of the surgical extraction when compared with horizontal, mesioangular type of impactions and simple cases. Similar cases that were treated with rotary systems have shown to be associated with a higher degree of swelling and trismus in all postoperative days.

Data analysis confirms that there was a significant correlation between postoperative swelling and bone removal with piezoelectric surgery in all the postoperative periods. This finding is not surprising since piezoelectric surgery decreases trauma to the bony structures, potentially decreasing inflammation (Basheer et al., 2017; Bhati et al., 2010; Chang et al., 2015; Goyal et al., 2012; Mantovani et al., 2013; Mistry et al., 2016; Piersanti et al., 2014). In contrast, this study found significantly less facial swelling in the cases of bone osteotomy combined with tooth sectioning, which is a risk factor for swelling (Kim et al., 2009; Sato et al., 2009). This result may be due to less initial injury to the PDL tissue compared to the rotary system (Chang et al., 2015).

The results have shown that the drawbacks of conventional rotary systems are reduced when using the piezoelectric technique, particularly regarding inferior alveolar nerve paresthesia, which is a distressing complication. Using a piezoelectric tip is highly advantageous in minimizing damage to soft tissues. In comparison, thermal trauma and accidental mechanical trauma such as soft tissue damage can occur with a high-speed drilling device (Chang et al., 2015; Ge et al., 2016).

The evidence in this comparative study gives us promising results. Patients reported significant postoperative satisfaction and minimal disturbance related to noise from the piezoelectric device. These results are consistent with the findings of a clinical study conducted by Chang et al. (2015), who confirmed that the piezoelectric device produced slightly lower noise levels than the conventional rotary systems. Although the piezoelectric device generated slightly lower noise levels than the high-speed rotary, their data showed that there were no significant differences in noise levels produced by the devices under different situations during third molar extraction between their experimental and control groups. Unfortunately, the observation of environmental noise levels was not included in the current study.

Results in the present study are similar to those presented by Goyal et al. (2012), Piersanti et al. (2014) who stated that piezoelectric surgery improved patient quality of life and reduced interference with daily life activity, as assessed by the PoSSe scale and subscales. However, analysis of the current data clarifies that in the cases of increased degree of difficulty of surgical extraction and in cases of combined bone osteotomy with tooth sectioning, piezoelectric surgery was

Table 3 Comparison of duration of surgery, pain, swelling, trismus, patient subjective experience and POSS scale in case of simple, moderate and difficult extractions according to the Pederson index in rotary vs piezoelectric surgery procedures at different follow-up periods.

		Difficulty index of Pederson								
		Simple extraction (n = 26)			Moderate extraction(n = 22)			Difficult extraction(n = 15)		
		Control group	Study group	P	Control group	Study group	P	Control group	Study group	P
Duration time (min)	Mean	13.65 ± 3.5	18.41 ± 4.3	0.27	17.52 ± 3.94	23.63 ± 4.74	0.011*	22.14 ± 5.86	31.2 ± 11.49	0.006†
	Minimum	7.00	11.30		11.40	15.00		16.80	26.00	
	Maximum	15.44	19.00		24.00	27.00		34.10	44.80	
Pain (mm) mean ± SD	Day 1	3.5 ± 2.15	2.41 ± 2.09	0.49	4.93 ± 2.88	3.36 ± 2.21	0.001†	6.42 ± 3.11	4.50 ± 3.11	0.000‡
	Day 3	2.32 ± 1.98	1.88 ± 1.52	0.34	3.84 ± 1.90	2.20 ± 1.90	0.001†	4.85 ± 2.75	2.90 ± 2.70	0.000‡
	Day 5	1.60 ± 1.43	1.39 ± 1.62	0.001†	2.51 ± 2.03	1.58 ± 01.47	0.001†	3.09 ± 2.44	1.77 ± 1.76	0.000‡
	Day 7	1.11 ± 0.9	0.70 ± 0.56	0.001†	1.40 ± 1.22	0.94 ± 0.63	0.001†	1.93 ± 1.76	1.15 ± 0.55	0.000‡
	Day 14	00	00	NA	0.45 ± 0.05	000	0.000‡	0.16 ± 0.07	000	0.000‡
Swelling (cm) mean ± SD	Base line	10.19 ± 0.73	10.17 ± 0.81	0.71	10.25 ± 0.95	10.14 ± 0.83	0.68	10.28 ± 0.97	10.11 ± 0.79	0.59
	Day 1	11.74 ± 1.22	10.79 ± 0.93	0.014*	12.17 ± 1.07	11.25 ± 1.38	0.001†	12.51 ± 2.23	11.52 ± 1.82	0.000‡
	Day 3	13.41 ± 1.79	11.81 ± 1.09	0.001†	14.21 ± 1.55	12.01 ± 1.23	0.000‡	14.95 ± 2.17	12.78 ± 1.69	0.000‡
	Day 5	12.52 ± 1.8	11.05 ± 0.89	0.001†	13.11 ± 1.17	11.86 ± 1.19	0.000‡	14.22 ± 1.96	12.03 ± 1.39	0.000‡
	Day 7	10.62 ± 0.81	10.26 ± 0.77	0.014*	10.97 ± 1.05	10.33 ± 0.92	0.000‡	11.15 ± 1.04	10.33 ± 0.91	0.000‡
	Day 14	10.22 ± 0.83	10.19 ± 0.89	0.63	10.62 ± 1.01	10.16 ± 0.81	0.001†	10.87 ± 1.21	10.15 ± 0.84	0.000‡
Trismus (mm) mean ± SD	Base line	45.29 ± 2.40	45.29 ± 2.40	NA	45.22 ± 2.73	45.22 ± 2.73	NA	45.19 ± 2.15	45.19 ± 2.15	NA
	Day 1	36.57 ± 3.29	43.26 ± 2.09	0.04*	33.72 ± 3.61	40.22 ± 2.81	0.000‡	31.84 ± 4.55	39.82 ± 3.37	0.000‡
	Day 3	31.62 ± 4.80	40.72 ± 4.02	0.001†	28.58 ± 5.71	37.92 ± 4.47	0.000‡	27.49 ± 6.33	37.05 ± 4.51	0.000‡
	Day 5	38.90 ± 3.71	43.91 ± 2.01	0.001†	36.01 ± 3.56	42.75 ± 2.32	0.000‡	34.81 ± 3.74	41.75 ± 3.05	0.000‡
	Day 7	40.06 ± 3.17	44.25 ± 1.11	0.000‡	39.96 ± 3.32	44.28 ± 2.11	0.000‡	38.34 ± 3.29	43.13 ± 2.68	0.000‡
	Day 14	45.09 ± 1.28	45.27 ± 0.24	0.40	44.28 ± 1.90	45.08 ± 2.49	0.000‡	43.19 ± 2.36	44.92 ± 2.32	0.000‡
Patient satisfaction of the Procedure/Patient satisfaction of noise Disturbance *(%)*	Very Satisfied	18(69.2)/13 (50)	23(88.46)/18 (69.23)	N.S/ P < 0.05	12(54.54)/4 (18.18)	19(78.36)/9 (40.90	P < 0.05/ P < 0.01	4(26.66)/1 (6.66)	8(53.33)/3(20)	P < 0.01/ P < 0.001
	Fairly Satisfied	6(23.07)/7 (26.92)	2(7.69)/6 (23.07)		5(22.72)/8 (36.36)	3(13.63)/6 (27.27)		6/(40)/4 (26.66)	4(26.66)/5 (33.33)	
	Fairly Unsatisfied	2(7.69)/4 (15.38)	1(3.84)/2(7.69)		3(13.63)/6 (27.27)	1(4.54)/4(8.18)		3(20)/6(40)	2(13.3)/4 (26.66)	
	Very Unsatisfied	0(00)/2(7.69)	0(00)/0(00)		2(9.09)/4 (18.18)	0(00)/2(9.09)		2(13.3)/4 (26.66)	1(6.66)/3(20)	
Posse Scale mean ± SD	Eating	10.21 ± 2.56	8.43 ± 2.14	P < 0 0.05	10.94 ± 2.81	8.52 ± 2.18	P < 0.01	12.06 ± 3.11	9.57 ± 2.39	P < 0.001
	Speech	2.52 ± 1.97	1.38 ± 1.22	P < 0.01	2.73 ± 2.04	1.55 ± 1.37	P < 0.01	2.90 ± 2.27	1.73 ± 1.46	P < 0.01
	Sensation	1.61 ± 2.0	1.43 ± 1.83	P < 0.05	1.64 ± 2.9	1.46 ± 1.88	P < 0.05	1.75 ± 3.18	1.52 ± 2.02	P < 0 0.05
	Appearance	6.56 ± 3.88	3.98 ± 2.06	P < 0.01	7.93 ± 4.21	4.46 ± 2.18	P < 0.001	9.17 ± 5.22	6.05 ± 2.39	P < 0.001
	Pain.	11.10 ± 9.12	7.02 ± 0.56	P < 0.01	14.01 ± 1.22	9.43 ± 6.31	P < 0.01	19.32 ± 7.62	11.51 ± 5.51	P < 0.001
	Sickness	0.82 ± 1.30	0.51 ± 1.14	P < 0.05	0.97 ± 1.46	0.66 ± 1.28	P < 0.05	1.16 ± 1.72	0.83 ± 1.43	P < 0 0.05
	Interference with daily activities	5.89 ± 2.96	3.18 ± 2. 7	P < 0.01	6.36 ± 3.12	4.40 ± 2.82	P < 0.001	7.78 ± 4.05	5.25 ± 2.99	P < 0.001
	Total score	38.71 ± 23.79	25.93 ± 11.65	P < 0.05	44.85 ± 17.76	30.48 ± 18.02	P < 0.001	54.14 ± 27.17	36.46 ± 18.19	P < 0.001

Abbreviations: Min, Minutes; mm, Millimeter; Cm, Centimeters; SD, Standard Deviation; %, percentage; NS, Non-significant; *P < 0.05; †P < 0.01; ‡P < 0.001.

Table 4 Comparison of duration of surgery, pain, swelling, trismus, patient subjective experience and POSS scale in case of surgical extractions requiring bone osteotomy alone or bone osteotomy combined tooth splitting in rotary vs piezoelectric surgery procedures at different follow-up periods.

		Surgical procedure					
		Bone osteotomy only(n = 28)			Bone osteotomy combined tooth splitting (n = 35)		
		Control group	Study group	P	Control group	Study group	P
Duration time (min)	Mean	19.41 ± 5.32	24.77 ± 6.64	0.015*	21.94 ± 6.07	28.37 ± 12.04	0.001†
	Minimum	8.57	13.62		12.24	19.28	
	Maximum	23.21	31.85		29.00	31.16	
Pain (mm) mean ± SD	Day 1	5.4 ± 1,93	3.32 ± 1.50	0.18	6.44 ± 2.01	4.1 ± 1.92	0.001†
	Day 3	4.1 ± 1.25	2.08 ± 1.23	0.011*	5.72 ± 1.68	2.7 ± 1.84	0.001†
	Day 5	2.87 ± 1.05	1.22 ± 1.16	0.001†	3.36 ± 1.33	1.49 ± 1.19	0.000‡
	Day 7	1.78 ± 0.94	0.93 ± 0.04	0.001†	2.05 ± 0,55	1.03 ± 0.07	0.000‡
	Day 14	0.44 ± 0.17	000	0.000‡	0.51 ± 0.34	000	0.000‡
Swelling (cm) mean ± SD	Base line	10.23 ± 0.92	10.21 ± 0.90	0.69	10.41 ± 0.87	10.39 ± 0.82	0.71
	Day 1	11.88 ± 1.16	10.83 ± 1.06	0.03*	12.39 ± 2.11	11.06 ± 1.37	0.000‡
	Day 3	13.57 ± 1.85	11.94 ± 1.15	0.000‡	14.76 ± 2.08	12.42 ± 1.55	0.000‡
	Day 5	12.33 ± 1.06	11.21 ± 0.97	0.000‡	13.81 ± 2.44	11.76 ± 1.38	0.000‡
	Day 7	11.57 ± 0.78	10.69 ± 0.58	0.001†	11.91 ± 1.49	10.44 ± 0.98	0.000‡
	Day 14	10.31 ± 0.94	10.22 ± 0.06	0.54	10.84 ± 0.92	10.40 ± 0.86	0.013*
Trismus (mm) mean ± SD	Base line	45.14 ± 2.57	45.14 ± 2.57	NA	45.18 ± 2.32	45.18 ± 2.32	NA
	Day 1	34.82 ± 3.46	40.96 ± 2.41	0.70	33.27 ± 4.03	40.02 ± 3.15	0.000‡
	Day 3	29.98 ± 5.58	38.22 ± 4.36	0.02*	28.96 ± 6.10	37.92 ± 4.20	0.000‡
	Day 5	36.74 ± 3.95	43.09 ± 2.28	0.001†	35.11 ± 3.81	42.16 ± 2.93	0.000‡
	Day 7	40.06 ± 3.17	44.20 ± 2.11	0.001†	39.55 ± 3.79	43.85 ± 2.59	0.000‡
	Day 14	44.02 ± 1.85	45.11 ± 2.49	0.000‡	43.95 ± 2.54	45.01 ± 2.11	0.000‡
Patient satisfaction of the procedure/Patient satisfaction of noise Disturbance *n (%)*	Very Satisfied	5(17.85)/4 (14.28)	19(67.85)/9 (32,14)	P < 0.01/ P < 0.01	10(28.57)/3 (10.71)	19(54.28)/9 (25.71)	P < 0.001/ P < 0.001
	Fairly Satisfied	14(50)/10 (35.71)	6(21.42)/11 (39.28)		13(37.14)/9 (25.71)	10(28.57)/11 (31.42)	
	Fairly Unsatisfied	8(28.57)/9 (32.14)	3(10.71)/6 (21.42)		7(20)/14(40)	4(11.42)/8 (22.85)	
	Very Unsatisfied	1(3.57)/5 (17.85)	0(00)/2(7.14)		5(14.28)/9 (25.71)	2(5.71)/7(20)	
Posse scale mean ± SD	Eating	11.07 ± 2.96	8.82 ± 2.31	P < 0.01	12.43 ± 3.23	9.66 ± 2.74	P < 0.001
	Speech	2.88 ± 2.17	1.67 ± 1.48	P < 0.01	3.13 ± 2.42	1.95 ± 1.88	P < 0.01
	Sensation	1.73 ± 2.96	1.52 ± 1.99	P < 0.05	1.86 ± 3.22	1.79 ± 2.25	P < 0 0.05
	Appearance	8.11 ± 4.38	4.72 ± 2.37	P < 0.001	9.92 ± 4.77	6.08 ± 2.50	P < 0.001
	Pain.	17.83 ± 9.45	9.32 ± 0.4	P < 0.01	20.51 ± 5.56	10.37 ± 0.78	P < 0.001
	Sickness	1.08 ± 1.53	0.73 ± 1.43	P < 0.05	1.39 ± 1.72	0.96 ± 1.64	P < 0 0.05
	Interference with daily activities	7.05 ± 3.63	4.86 ± 3.07	P < 0.001	8.85 ± 4.33	5.49 ± 3.60	P < 0.001
	Total score	49.75 ± 27.08	31.64 ± 13.05	P < 0.001	58.09 ± 25.07	36.30 ± 15.39	P < 0.001

Abbreviations: Min, Minutes; mm, Millimeter; Cm, Centimeters; SD, Standard Deviation; %, percentage; NS, Non-significant; *P < 0.05; †P < 0.01; ‡P < 0.001.

significantly better compare to the rotary systems in all the PoSSe subscales.

The duration of the surgical procedure versus postoperative complications is a rather controversial matter to investigate. Although all of the previously mentioned reports considered the mean value to statistically analyze the duration of all procedures, piezoelectric surgery required longer time compared to the conventional rotary instrument. However, the current trial analyzed the surgical time according to the difficulty and specific operative variable for each surgical procedure in both groups.

Several investigators (Al-Delayme,2013; Baqain et al., 2002; Bello et al., 2011; Bouloux et al., 2007; Jerjes et al., 2010; Graziani et al., 2006; Kim et al., 2006) have stated that the procedure duration significantly correlates with postoperative complications and morbidity after surgical extraction of lower third molar. The present results demonstrated that prolonged piezoelectric surgery did not significantly influence the analyzed outcomes.

Other studies (Conrad et al., 1999, Phillips et al., 2003) reported that patients whose surgery time was 30 min or longer using rotary systems device had a prolonged recovery. This is

Table 5 Summary of variables according to presence of inferior alveolar nerve paresthesia and recovery after the surgery in both groups.

Variables	Control group	Study group
Gender		
M	1(1.58)	1(1.58)
F	2(3.17)	0(00)
Age (years)		
17.5–25	2(3.17)	1(1.58)
> 25	1(1.58)	0(00)
Winter's classification		
Vertical	1(1.58)	0(00)
Distoangular	2(3.17)	1(1.58)
Pell and Gregory classification		
IIC	1(1.58)	0(00)
IIIC	2(3.17)	1(1.58)
Difficulty index of Pederson		
Moderate	1(1.58)	1(1.58)
Difficult	2(3.17)	0(00)
No. of roots		
Multiple	2(3.17)	1(1.58)
Singular	1(1.58)	0(00)
Indication for removal		
Prophylactic removal	3(4.76)	0(00)
Orthodontic reason	0(00)	1(1.58)
Recovery after the surgery		
Less than 1 month	2(3.17)	1(1.58)
1–6 months	0(00)	0(00)
6–12 months	1(1.58)	0(00)

noteworthy because piezoelectric surgery lasting more than 30 min resulted in a statistically significant reduction in postoperative morbidity compared to cases lasting less than 20 min with the rotary system.

Surgical procedures using piezoelectric surgery had significantly faster postoperative recovery compared to the traditional rotary systems, which can be attributed to many factors. Piezoelectric surgery has a cavitation phenomenon: an implosion of gas bullae into blood vessels during osteotomy, producing bone cutting which produces a hemostatic effects and reducing blood loss (Horton et al., 1975). Piezoelectric surgery plays an important role in increasing bone density within the extraction socket and in decreasing the amount of bone loss along the distal aspect of the mandibular second molar (Arakji et al., 2016). The piezoelectric surgery unit cuts bone like a chisel rather than burnishing it with a rotary bur. The bone samples harvested with the Piezoelectric devices were characterized by the integrity of bony structure, well-designed osteotomy lines, and no evidence of bone heat osteonecrosis (Rullo et al., 2013).

Double blinding was not possible in this particular study and therefore a single blinded study poses a limitation. There is also a limited sample which may result in restricted power. To obtain more profound results, future randomized studies should use different detailed radiographical and histological evaluation methods to add more valuable findings and analyze all variables that can influence third molar surgery using piezoelectric surgery and conventional rotary systems technique.

5. Conclusions

In conclusion, our study indicates that piozelectric surgery is more reliable, effective, and valuable for surgically removing impacted mandibular third molars compared to traditional rotary systems. Piezoelectric surgery effectively decreases postoperative swelling, pain, and trismus. Furthermore, the piezoelectric technique was preferred by patients who reported improved postoperative quality of life and less disturbance related to noise, features that lead to a significant positive effect in patients' psychological stress and anxiety. Piezoelectric surgery should be considered a viable alternative technique compared to the conventional rotary systems. It is advised that this may be the preferred modality for patients undergoing complicated surgical extraction of impacted lower third molars.

Ethics statement/confirmation of patient permission

Research Involving Human Participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All of the patients were told about the operation, healing time, and possible complications. The protocol design was approved by the local ethics committee. All participants provided written informed consent

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Declaration of Competing 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.

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Informed consent

All participants provided written informed consent.

References

Al-Delayme, R.M., 2013. The effect of cigarette smoking on the severity of pain, swelling and trismus after the surgical extraction of impacted mandibular third molar. J. Clin. Exp. Dent. 5 (3), e117–e121.

Alvira-González, J., Figueiredo, R., Valmaseda-Castellón, E., Quesada-Gómez, C., Gay-Escoda, C., 2017. Predictive factors of difficulty in lower third molar extraction: a prospective cohort study. Med. Oral Patol. Oral Cir. Bucal.1;22(1):e108–e114.

Arakji, H., Shokry, M., Aboelsaad, N., 2016. Comparison of piezosurgery and conventional rotary instruments for removal of impacted mandibular third molars: a randomized controlled clinical and radiographic trial. Int. J. Dent. 2016, 8169356.
Badenoch-Jones, E.K., David, M., Lincoln, T., 2016. Piezoelectric compared with conventional rotary osteotomy for the prevention of postoperative sequelae and complications after surgical extraction of mandibular third molars: a systematic review and meta-analysis. Br. J. Oral Maxillofac. Surg. 54 (10), 1066–1079.
Bartuli, F.N., Luciani, F., Caddeo, F., 2013. Piezosurgery vs high speed rotary handpiece: a comparison between the two techniques in the impacted third molar surgery. Oral Implantol. (Rome) 15;6 (1), 5–10.
Basheer, S.A., Govind, R.J., Daniel, A., Sam, G., Adarsh, V.J., Rao, A., 2017. Comparative study of piezoelectric and rotary osteotomy technique for third molar impaction. J. Contemp. Dent. Pract. 18 (1), 60–64.
Baqain, Z.H., Al-Shafii, A., Hamdan, A.A., Sawair, F.A., 2012. Flap design and mandibular third molar surgery: a split mouth randomized clinical study. Int. J. Oral Maxillofac. Surg. 41, 1020–1024.
Bhati, B., Kukreja, P., Kumar, S., Rathi, V., Singh, K., Bansal, Sh., 2017. Piezosurgery versus rotatory osteotomy in mandibular impacted third molar extraction. Ann. Maxillofac. Surg. 7 (1), 5–10.
Bello, S.A., Adeyemo, W.L., Bamgbose, B.O., Obi, E.V., Adeyinka, A. A., 2011. Effect of age, impaction types and operative time on inflammatory tissue reactions following lower third molar surgery. Head Face Med. 2011 (7), 8.
Bouloux, G.F., Steed, M.B., Perciaccante, V.J., 2007. Complications of third molar surgery. Oral Maxillofac. Surg. Clin. North Am. 19 (117–28), vii.
Chang, H.H., Lee, M.S., Hsu, Y.C., Tsai, S.J., Lin, C.P., 2015. Comparison of clinical parameters and environmental noise levels between regular surgery and piezosurgery for extraction of impacted third molars. J. Formos. Med. Assoc. 114 (10), 929–935.
Conrad, S.M., Blakey, G.H., Shugars, D.A., 1999. Patients' perception of recovery after third molar surgery. J. Oral Maxillofac. Surg. 57, 1288.
Ge, J., Yang, C., Zheng, J., Qian, W., 2016. Piezosurgery for the lingual split technique in lingual positioned impacted mandibular third molar removal: a retrospective study. Medicine (Baltimore) 95, (12) e3192.
Gorecki, P., Rainsford, K.D., Taneja, P., Bulsara, Y., Pearson, D., Saund, D., Ahmed, B., Dietrich, T., 2017. Submucosal diclofenac for acute postoperative pain in third molar surgery: a randomized. Controlled Clin. Trial. J. Dent. Res. 1. 22034517744207.
Goyal, M., Marya, K., Jhamb, A., Chawla, S., Sonoo, P.R., Singh, V., Aggarwal, A., 2012. Comparative evaluation of surgical outcome after removal of impacted mandibular third molars using a Piezotome or a conventional handpiece: a prospective study. Br. J. Oral Maxillofac. Surg. 50 (6), 556–561.
Graziani, F., D'Aiuto, F., Arduino, P.G., Tonelli, M., Gabriele, M., 2006. Perioperative dexamethasone reduces post-surgical sequelae of wisdom tooth removal. A split mouth randomized double-masked clinical trial. Int. J. Oral Maxillofac. Surg. 35, 241–246.
Gülşen, Şentürk, 2017. Pain following third molar surgery: a split mouth control study BMC Oral Health 17, 79.
Gülnahar, Y., Hüseyin Köşger, H., Tutar, Y.A., 2013. comparison of piezosurgery and conventional surgery by heat shock protein 70 expression. Int. J. Oral Maxillofac. Surg. 42 (4), 508–510.
Horton, J.E., Tarpley Jr., T.M., Wood, L.D., 1975. The healing of surgical defects in alveolar bone produced with ultrasonic instrumentation, chisel, and rotary bur. Oral Surg. Oral Med. Oral Pathol. 39, 536–546.
Jiang, Q., Qiu, Y., Yang, C., Yang, J., Chen, M., Zhang, Z., 2015. Piezoelectric versus conventional rotary techniques for impacted third molar extraction: a meta-analysis of randomized controlled trials. Medicine 94(41), e1685.
Jerjes, W., El-Maaytah, M., Swinson, B., Banu, B., Upile, T., D'Sa, S., 2006. Experience versus complication rate in third molar surgery. Head Face Med. 2, 14.
Jerjes, W., Upile, T., Shah, P., 2010. Risk factors associated with injury to the inferior alveolar and lingual nerves following third molar surgery—revisited. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. 109, 335.
Kahraman, S., Cetiner, S., Straus, R., 2017. The effects of transcutaneous and intraoral low-level laser therapy after extraction of lower third molars: a randomized single blind, placebo controlled dual-center study. Photomed. Laser Surg., 401–440
Kim, J.C., Choi, S.S., Wang, S.J., Kim, S.G., 2006. Minor complications after mandibular third molar surgery: type, incidence, and possible prevention. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod. A 102 (2), e4–e11.
Labanca, M., Azzola, F., Vinci, R., 2008. Piezoelectric surgery: twenty years of use. Br. J. Oral Maxillofac. Surg. 46, 265–269.
Mantovani, E., Arduino, P.G., Schierano, G., Ferrero, L., Gallesio, G., Mozzati, M., Russo, A., Scully, C., Carossa, S.A., 2014. split-mouth randomized clinical trial to evaluate the performance of piezosurgery compared with traditional technique in lower wisdom tooth removal. J. Oral Maxillofac. Surg. 72 (10), 1890–1897.
Maurer, P., Kriwalsky, M.S., Block Veras, R., Brandt, J., Heiss, C., 2007. Light microscopic examination of rabbit skulls following conventional and Piezosurgery osteotomy. Biomed. Tech. (Berl.) 52, 351–355.
Mistry, F.K., Hegde, N.D., Hegde, M.N., 2016. Postsurgical consequences in lower third molar surgical extraction using micromotor and piezosurgery. Ann. Maxillofac. Surg. 6 (2), 251–259.
Ottria, L., Luciani, F., Piva, P., Alagna, A.M., Arcuri, C., Bartuli, F. N., 2017. The flap recovery on the impacted lower third molar surgery comparing 3 different flap designs: a clinical study. Oral Implantol. (Rome) 30;10 (3), 270–275.
Phillips, C., White, R.P., Shugars, D.A., 2003. Risk factors associatedwith prolonged recovery and delayed healing after third molar surgery. J. Oral Maxillofac. Surg. 61, 1436.
Piersanti, L., Dilorenzo, M., Monaco, G., Marchetti, C., 2014. Piezosurgery or conventional rotatory instruments for inferior third molar extractions?. J. Oral Maxillofac. Surg. 72 (9), 1647–1652.
Ruga, E., Gallesio, C., Boffano, P., 2011. Platelet-rich fibrin and piezoelectric surgery: a safe technique for prevention of periodontal complications in third molar surgery. J Craniofac Surg. 22 (5), 1951–1955.
Rullo, R., Addabbo, F., Papaccio, G., D'Aquino, R., Festa, V.M., 2013. Piezoelectric device vs. conventional rotative instruments in impacted third molar surgery: relationships between surgical difficulty and postoperative pain with histological evaluations. J. Craniomaxillofac. Surg. 41 (2), e33–e38.
Ruta, D.A., Bissias, E., Ogston, S., Ogden, G.R., 2000. Assessing health outcomes after extraction of third molars: the postoperative symptom severity (PoSSe) scale. Br. J. Oral Maxillofac. Surg. 38, 480–487.
Sato, F.R., Asprino, L., de Araújo, D.E., de Moraes, M., 2009. Short-term outcome of postoperative patient recovery perception after surgical removal of third molars. J. Oral Maxillofac. Surg. 67 (5), 1083–1091.
Sortino, F., Pedullà, E., Masoli, V., 2008. The piezoelectric and rotatory osteotomy technique in impacted third molar surgery: comparison of postoperative recovery. J. Oral Maxillofac. Surg. 66, 2444–2448.
Troedhan, A., Kurrek, A., Wainwright, M., 2011. Ultrasonic piezotome surgery: Is it a benefit for our patients and does it extend surgery time? A retrospective comparative study on the removal of 100 impacted mandibular 3rd molars. Open J. Stomatol. 1, 179–184.

Vercellotti, T., 2004. Technological characteristics and clinical indications of piezoelectric bone surgery. Minerva Stomatol. 53, 207–214.
Yuasa, H., Kawai, T., Sugiura, M., 2002. Classification of surgical difficulty in extracting impacted third molars. Br. J. Oral Maxillofac. Surg. 40 (1), 26–31.
Zandi, M., Amini, P., Keshavarz, A., 2016. Effectiveness of cold therapy in reducing pain, trismus, and oedema after impacted mandibular third molar surgery: a randomized, self-controlled, observer-blind, split-mouth clinical trial. Int. J. Oral Maxillofac. Surg. 45, 118–123.