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Original research

Cryotherapy versus Ultrasound on Temporomandibular Joint Dysfunction after Surgical Tooth Extraction. A randomized controlled study.

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Abstract

Background: Disorders of the temporomandibular joint (TMJ) due to surgical tooth extraction have a negative impact on jaw function due to pain and locking in the TMJ, causing patients to present with limited mouth opening or difficulty chewing. **Purpose:** This study compared between the therapeutic effects of cryotherapy and ultrasound on TMJ dysfunction (maximum mouth opening and pain) after surgical tooth extraction. **Methods:** A randomized controlled trial enrolled 40 patients diagnosed with TMJ dysfunction after surgical tooth extraction, aged 30-60 years. Participants were randomly assigned into two groups (n=20/group): *Group A:* Cryotherapy in addition to traditional physiotherapy program (deep friction massage, stretching exercises and jaw exercises). *Group B:* Ultrasound therapy in addition to traditional physiotherapy program, all treatments were applied for one week, three times/week. Maximum mouth opening (MMO) was assessed using Boley Gauge Caliper and pain accompanying TMJ dysfunction was assessed using Visual Analogue Scale (VAS) at baseline, post treatment and follow-up after one week from treatment. **Results:** There was a significant difference ($P<0.05$) between the two groups in mean ±SD values of MMO and VAS ($P=0.001$) at post-treatment and at follow-up. This significant increase in MMO ($P=0.0001$) and significant decrease in VAS ($P=0.005$) is favorable in ultrasound therapy group than cryotherapy group. **Conclusion:** Both interventions appear to be effective in improving MMO and pain in patients with TMJ dysfunction after surgical tooth extraction, but ultrasound therapy not only provided superior immediate improvement but also resulted in more lasting benefits at one week after treatment compared to cryotherapy. Adding ultrasound therapy to traditional physiotherapy program is crucial for the management of TMJ dysfunction after surgical tooth extraction.

Keywords: Cryotherapy, Ultrasound, TMJ dysfunction, Surgical Tooth Extraction, Maximum mouth opening, Visual Analogue Scale.

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INTRODUCTION:

The temporomandibular joint consists of the mandible and the temporal bone, creating a bilateral synovial joint that operates as a one unit. The right and left joints cannot act independently because the TMJ is linked to the mandible. This joint is the sole mobile joint within the skull. Proper functioning of the jaw—such as when biting, chewing, swallowing, and speaking—depends on the stability and movement of the mandible [1].

Temporomandibular disorders (TMDs) affect the temporomandibular joint and muscles that move the joint, so symptoms like pain, discomfort, and limited jaw movement are frequently present with these disorders [2]. Nayak, M. M. et al. also defined temporomandibular joint dysfunction (TMD, TMJD) as a medical condition that refers to discomfort and functional limitation of the masticatory muscles moving the jaw and the temporomandibular joint that connect the mandible to the skull [3].

TMDs can cause functional difficulties, such as trouble eating, speaking, or sleeping, which has a substantial influence on an individual's overall quality of life. Additionally, the persistent pain brought on by TMDs may result in psychological problems such as social isolation, anxiety, and despair. TMDs can have a substantial financial burden in addition to their physical and psychological effects because of the costs associated with treatment, lost productivity, and decreased quality of life [4].

The most frequently cited causes of temporomandibular disorders, either individually or in combination, include mental stress, dysfunctional attitudes, malocclusion, hormonal fluctuations, muscles of mastication dysfunction, and abnormal structure of the TMJ [5].

Tooth extraction is a frequently employed method for creating additional space in the dental arch during orthodontic procedures. The extraction of first premolars in orthodontics may influence jaw movements, as indicated by the higher values of the axiographic parameters (three-dimensional investigation) describing condylar movements during protrusion, retrusion, and speech activities. Consequently, extracting the premolars leads to a lasting structural and functional alteration in the patient's stomatognathic system (an anatomical system comprising the teeth, jaws, and associated soft tissues), resulting in medium and long-term effects on the craniomandibular system that are largely overlooked [6, 7].

Hemorrhage, alveolitis, alveolar osteitis, bleeding, abscesses, dehiscence, fracture of the maxillary and/or mandibular tuberosity bone, damage to the inferior alveolar nerve, pain, swelling, damage to neighboring teeth, trismus, infection, and stomatognathic system dysfunctions are among the various morbidities that can arise from a surgical procedure. Third molar extractions have a number of risks, including the potential for temporomandibular joint (TMJ) injury, which can result in temporomandibular disorders (TMDs), the most common chronic cause of orofacial discomfort [8].

One frequent side effect of tooth extraction is TMD. According to a study, 48% of TMD patients linked a specific incident, such as extensive oral surgical procedures, to the start of their symptoms. Research has indicated that tooth extraction may result in temporomandibular joint disease; however, more research is necessary to determine the precise causes [9].

Trismus, which refers to the difficulty in opening the mouth, often occurs due to surgical trauma and is commonly associated with inflammation of the masticatory muscles following the removal of lower third molars. The medial pterygoid muscle is the muscle that is most often injured as a result of needle trauma, swelling, bleeding, or inflammation. Elevated local tissue temperature, enhanced blood circulation, and improved tissue elasticity and extensibility, along with decreased fluid viscosity, greatly reduce the inflammatory mediators and tension in the chewing muscles, leading to better mouth opening [10].

Issues like pain, trismus, and swelling often arise following dentoalveolar surgeries. These aftereffects are anticipated and regarded as typical physiological reactions to surgery.

While these postoperative complications are expected and typically resolve quickly, they can negatively impact the patient's quality of life, so it is important to minimize them [11].

Different interventions are described in the literature that could be effective in the management of TMJ disorders after surgical tooth extraction:

Many of the drugs that are commonly prescribed for the treatment of TMD, some of these drugs work to treat muscle soreness, and others are utilized to alleviate the joint pain associated with TMDs [12.] Orthodontists typically recommend either orthopedic stabilization therapy or occlusal splint therapy to treat their TMD patients [13].

Two of the most common surgical procedures for internal TMJ derangements or degenerative pathologies are arthrocentesis (joint aspiration) that removes fluid from swollen joints, with or without drug injection, and arthroscopy that allows the visualization of the inner tissues of the TMJ for diagnostic purposes and subsequent targeted treatment of the visualized tissues, i.e., the lysis of adhesions or injection of medication into the inflamed tissue [12,14].

Complications from TMJ surgery can be divided in true complications and untoward outcomes such as damage to adjacent anatomic structures, infections, neurovascular, autoimmune, and Biomechanical complications [15]. So, there is need for Physiotherapy in the treatment of TMJ disorders as it is a noninvasive method that could constitute the prevention of pain, improvement of the functions of TMJ and increasing the quality of daily life [16].

The field of physiotherapy uses a variety of methods to treat patients' pain, reduce inflammation, and regain motor abilities. These methods include biophysical modalities (eg, low-level laser therapy [LLLT], transcutaneous electrical nerve stimulation [TENS], ultrasound, and shortwave therapy), manual therapy (eg, joint mobilization/manipulations, soft-tissue mobilization), exercise therapy, acupuncture, and dry needling (DN) [17]. Patients suffering from TMD can achieve considerable symptom relief when manual therapy is paired with exercise, optimizing the effectiveness of each treatment on its own. There is currently insufficient data to support the use of biophysical modalities to relieve pain in TMD patients [12].

Cryotherapy has been used to treat a variety of illnesses and conditions since ancient medicine. It is a non-pharmacological technique for managing pain. There are two methods that applying cold might effectively reduce pain. First, by removing muscular spasm and edema, cold treatment eases or lessens discomfort. Second, by reducing or stopping peripheral nerve transmission, it effectively reduces pain. With cryotherapy, mandibular mobility increases, TMJ stiffness decreases, and discomfort decreases [18,19].

Applying cold reduces the temperature of soft tissues including the skin, which results in vasoconstriction that narrows blood vessels and stops blood flow. Moreover, it decreases conduction rate, inflammation, neural excitability, and tissue metabolism. Cryotherapy is indicated when there is swelling in damaged tissues, postoperative discomfort, tooth extraction, and oral surgical operations [20].

Therapeutic ultrasound therapy is one of the most effective ways to lessen pain, reduce muscular tension, and enhance muscle function. It is made up of three types of signals: constant waves, sound impulses, and ultrasound paired with stimulating current, which is the most useful [18].

Therapeutic ultrasound produces a range of biophysical effects that are typically categorized as thermal and non-thermal. The thermal effects of ultrasound vary according to the absorption coefficient of particular tissues, where tissues with higher collagen levels exhibit greater absorption, while those with higher water content demonstrate reduced absorption [3]. Ultrasound (US) is acknowledged as a stimulator when applied at a low intensity and may promote neovascularization, the differentiation of mesenchymal stem cells, and the localized release of angiogenic factors that influence ischemic tissues through enhanced blood circulation. Therefore, it has been investigated for its potential in addressing

hypoxia-induced chondrocyte injury in temporomandibular disorders [21].

Therefore, the objective of this research is to investigate the more effective treatment from cryotherapy and ultrasound on the outcomes of maximum mouth opening and pain in patients with TMJ dysfunction after surgical tooth extraction.

METHODS

Study design:

This research utilized a randomized controlled design and was carried out in the outpatient dental clinics of the Faculty of Oral and Dental Surgery at MUST University from March 2024 to September 2024. The Ethical Committee of Cairo University Physiotherapy approved the study on April 2, 2024 (No: P.T.REC/012/005201). Prior to participation, all subjects were informed about the publication of the collected data and provided their written informed consent, as well as details about the treatment's nature and the measurement devices involved. Patients were advised to report any side effects experienced during the treatment.

Sample size:

The calculation of the sample size for this research was performed using the G*power program 3.1.9 (G power program version 3.1, Heinrich-Heine-University, Düsseldorf, Germany) for a two-tailed test. The sample size determination was based on t-tests (comparing means: difference between two independent means in two groups), with a type I error set at alpha = 0.05, a power level of (1-βeta = 0.80), and the effect size d = 0.9710411, leading to a total sample requirement of 36 participants for comparing 2 independent groups and 2 key variable outcomes. Taking into account a 10% dropout rate, the minimum recommended sample size for this study was 40 participants (with at least 20 individuals in each group).

Subjects Enrollment:

A total of forty patients (19 males and 21 females) experienced TMJ dysfunction following surgical tooth extraction. They were chosen from Dental Clinics and randomly assigned into two equal groups. Their ages varied between 30 and 60 years. In this research, the patients were randomly segmented into two groups of equal size (20 patients in each group).

To ensure the groups were comparable, patients were randomly distributed (n = 20/group) into two separate groups (A and B) utilizing a concealed allocation method. Strict allocation concealment was upheld by employing sealed, opaque envelopes.

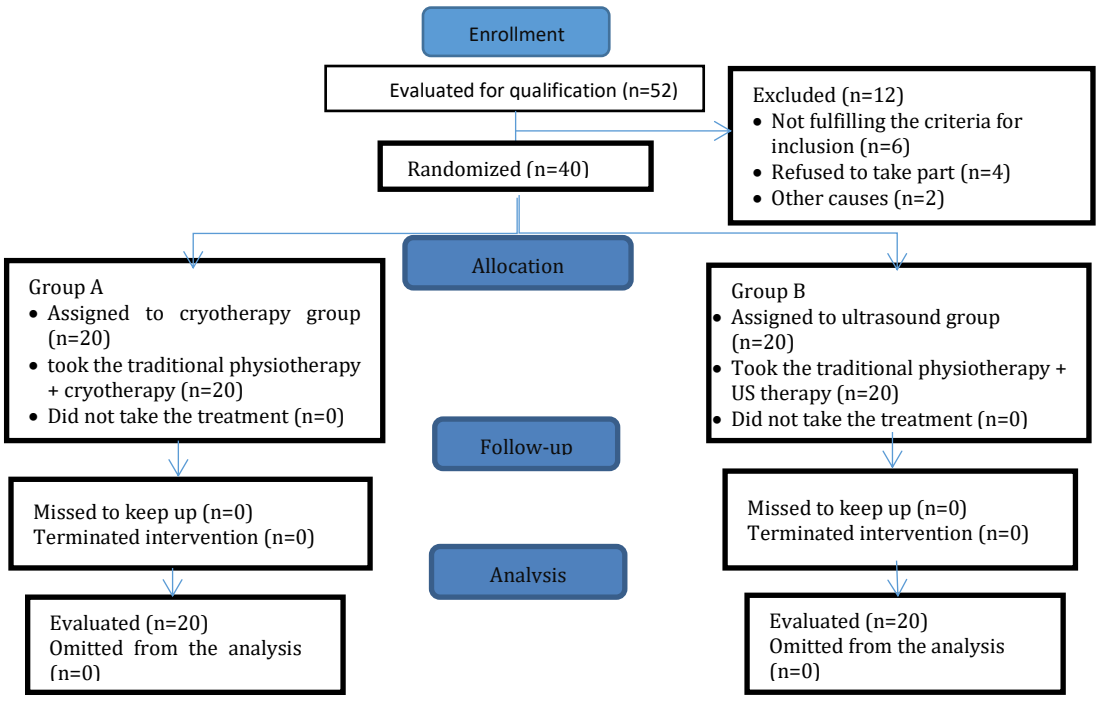

Figure (1): Flow chart

Inclusive criteria:

Patients with TMJ dysfunction due to surgical extraction of any tooth, the patients' ages varied from 30 to 60 years, and individuals from both genders were included in the selection. They were free from any other pathological conditions or histories except TMJ dysfunction after surgical tooth extraction.

Exclusive criteria:

Patients experiencing TMJ dysfunction due to other reasons, those with cardiac pacemakers or other implanted electronic devices, individuals with systemic diseases that could affect the study's goals, such as diabetes mellitus, suffered from mental or psychological disorders, Pregnant women, or patients who were uncooperative.

***Assessment procedure*:**

All participants underwent a comprehensive evaluation and recording of all relevant parameters at baseline, post treatment and at follow-up after one week post interventions.

Assessment of maximum mouth opening:

Using Boley Gauge Caliper for maximum mouth opening (MMO) measurements before, after the duration of therapeutic interventions and at follow-up after one-week.

Normal mouth opening is defined as the measurement between the incisors or the measurement between the incisors combined with the overbite. Interincisal opening is the greatest distance measured between the incisal edges of the upper central incisors and the lower central incisors at the midline when the mouth is opened fully. Measuring the interincisal distance, along with overbite, reflects the vertical distance that the mandible covers. A wide range of mouth-opening abilities is generally considered normal. Research shows that adults exhibit values ranging from 32 mm to 77 mm. The common range for intrinsic vertical mouth opening is 40-50 mm, with a functional range of 25-35 mm, and severe restrictions occurring at 10-24 mm [22].

The vertical distance between the central incisors of the maxillary and mandibular teeth illustrates the TMJ functional range of movement and the maximum mouth opening (MMO) or Maximum Interincisal Distance (MID). The Boley's gauge is one of the common tools used to measure MID [23]. Gauge calipers are currently regarded as the gold standard (accurate and repeatable) for performing tooth width measurements [24].

Participants were positioned in an upright posture (90º). They were instructed to open their mouths as wide as they could without assistance until no further movement was achievable. The measurement from the midline between the incisal edge of the upper incisors and the incisal edge of the lower incisors was taken with a Boley Gauge Caliper, and the results were documented in millimeters.

Assessment of pain accompanying TMJ dysfunction:

Using Visual Analogue Scale (VAS) to assess pain accompanying TMJ dysfunction during activity at the time of assessment before**,** after the duration of therapeutic interventions and at follow-up after one-week.

Widely, the Visual Analog Scale (VAS) is commonly employed to evaluate pain severity. Research has shown that VAS is a valid, reliable, and interval measurement tool. The repeatability and reliability of VAS are very high. Although it has a defined zero point, the VAS can be classified as a ratio scale that consists of a 10cm line, with two end points representing 0 (no pain) and 10 (maximum pain). A study has indicated that the VAS effectively represents ratios or levels of pain intensity while incorporating a zero point. This scale is simple and employs an eleven-point numeric system for subjective assessment [25]**.**

Treatment procedure:

I. Group A (cryotherapy group):

In this group of the study, 20 patients (11 males and 9 females) whom had TMJ dysfunction after surgical tooth extraction received cryotherapy in addition to traditional physiotherapy (deep friction massage, stretching exercises and jaw exercises) for one week. The cryotherapy was applied 3 times for one week (10–15 minutes) [18]. Cryotherapy was applied directly over the skin of TMJ. Massaging with ice cubes was applied in a slow circular movement **(Figure 2).**

Figure (2): Cryotherapy intervention

II. Group B (Ultrasound therapy group):

In this group of the study, 20 patients (8 males and 12 females) whom had TMJ dysfunction after surgical tooth extraction received ultrasound therapy in addition to traditional physiotherapy (deep friction massage, stretching exercises and jaw exercises) for one week. The application of Ultrasound therapy was three times for one week for five minutes in each session. Ultrasound was applied directly over the skin of TMJ. Ultra sound was applied in a slow circular movement. The parameters of ultrasound were continuous, 1 MHZ, 0.5 W/cm^2 for five minutes per session [18] **(Figure 3).**

Figure (3): Ultrasound intervention

Statistical analysis:

The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). The following statistical procedures were performed by using: Quantitative data including the mean and standard deviation for age, MMO, and VAS variables, Qualitative data including the frequency and percentage for gender variable, Shapiro-Wilk test was used to test the normal distribution of the study main variable outcomes and it was insignificant (P>0.05), for both outcomes, therefore, independent t-test was used to compare between both groups for patients age variable, Chi-square test was used to compare between both groups for patient's gender variable, and Multivariate analysis of variance (MANOVA) was used to compare the tested major dependent variables of interest (MMO and VAS) at different tested groups and measuring periods. Mixed design 2 x 3 MANOVA-test was used, the first independent variable (between subject factors) was the tested groups with 2 levels (cryotherapy group vs. ultrasound therapy group) and the second independent variable (within subject factor) was measuring periods with 3 levels (pre-assessment, post-treatment, and at follow-up after one week from treatment). Bonferroni correction test (Post hoc-tests) was used to compare between pairwise within and between groups of the tested variables which P-value was significant from MANOVA test. All statistical analyses for quantitative and qualitative data were significant at a probability level of ≤ 0.05 ($P \leq 0.05$).

RESULTS

This research was conducted to evaluate the therapeutic effects of cryotherapy and ultrasound on TMJ dysfunction following surgical tooth extraction. In this study, patients were randomly assigned into two equal groups: the cryotherapy group (n=20) and the ultrasound therapy group (n=20).

1. General characteristics of patients

The statistical evaluation indicated no significant differences (P>0.05) in the ages of the patients (P=0.748) or in the gender distribution of the patients (P=0.342) between the cryotherapy and ultrasound therapy groups.

Table (1): Comparison of general characteristics between both groups

Items	Age (Year)	Gender	
		Males	Females
Cryotherapy group (n=20)	43.40 ±7.80	11 (55.00%)	9 (45.00%)
Ultrasound group (n=20)	44.25 ±8.77	8 (40.00%)	12 (60.00%)
Statistic test value *	0.324	0.902	
P-value	0.748	0.342	
Significance	NS	NS	

*Quantitative data (age) are expressed as mean ±standard deviation and compared statistically by independent t-test
*Qualitative data (gender) are expressed as mean ±standard deviation and compared statistically by Chi-square test
P-value: probability value NS: non-significant (P>0.05)

2. Maximum mouth opening (MMO)

2.1. MMO within group comparisons

The cryotherapy group showed a statistically significant increase in maximum mouth opening (MMO) following treatment and at a one-week follow-up. There was a significant increase in MMO (P=0.0001), with a change of 0.59 cm in MMO and a 32.78% improvement from pre-assessment to post-treatment. A significant increase in MMO (P=0.0001) was also observed at the follow-up (one week after treatment), with a change of 0.86 cm and a 47.78% improvement from pre-assessment to follow-up. The increase in MMO between post-treatment and follow-up was statistically insignificant (P=0.149), with a change of 0.27 cm and an 11.30% improvement observed from post-treatment to the follow-up.

The ultrasound therapy group also demonstrated significant improvements in maximum mouth opening (MMO) following treatment and at a one-week follow-up. There was a significant increase in MMO (P=0.0001), with a change of 1.38 cm in MMO and a 74.59% improvement from pre-assessment to post-treatment. A significant increase in MMO (P=0.0001) was also observed at the follow-up (one week after treatment), with a change of 1.80 cm and a 97.30% improvement from pre-assessment to follow-up. There was a statistically significant increase in MMO (P=0.0001) from post-treatment to follow-up, with a change of 0.42 cm and a 13.00% improvement observed from post-treatment to the follow-up **(Table 2).**

Table (2): MMO within group comparisons

Items	Cryotherapy group (n=20)	Ultrasound group (n=20)
MMO among 3 assessment points within each group		
Pre-assessment	1.80 ±0.41	1.85 ±0.42
Post-treatment	2.39 ±0.43	3.23 ±0.45
Follow-up after one week	2.66 ±0.43	3.65 ±0.42
F-value	20.625	35.557
P-value	0.0001*	0.0001*
Significance	S	S
MMO between pre-assessment and at post-treatment within each group		
Pre-assessment	1.80 ±0.41	1.85 ±0.42
Post-treatment	2.39 ±0.43	3.23 ±0.45
Change (MD)	0.59	1.38
95% CI	0.25 – 0.93	1.22 – 1.54
Improvement %	32.78%	74.59%
F-value	12.589	21.543
P-value	0.0001*	0.0001*
Significance	S	S

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MMO between pre-assessment and follow-up within each group		
Pre-assessment	1.80 ±0.41	1.85 ±0.42
Follow-up after one week	2.66 ±0.43	3.65 ±0.42
Change (MD)	0.86	1.80
95% CI	0.42 – 1.30	1.24 – 2.36
Improvement %	47.78%	97.30%
F-value	15.230	23.517
P-value	0.0001*	0.0001*
Significance	S	S
MMO between post-treatment and follow-up within each group		
Post-treatment	2.39 ±0.43	3.23 ±0.45
Follow-up after one week	2.66 ±0.43	3.65 ±0.42
Change (MD)	0.27	0.42
95% CI	-0.06 – 0.60	0.18 – 0.66
Improvement %	11.30%	13.00%
F-value	0.657	11.938
P-value	0.149	0.0001*
Significance	NS	S

Data are expressed as mean ±standard deviation MD: Mean difference (change) 95% CI: confidence interval
P-value: probability value S: significant * Significant (P<0.05) NS: non-significant

2.2. MMO between group comparisons

No statistically significant difference was found between the two groups in the pre-assessment phase with mean difference between the two groups is very small (0.05), and the confidence interval includes zero (-0.26 to 0.36). There was a significant improvement in MMO post-treatment for both groups, but ultrasound therapy showed a much greater improvement compared to cryotherapy, the mean difference is 0.84, and the entire confidence interval (0.71 to 0.97) is above zero, indicating a significant difference between the two groups. Therefore, ultrasound therapy was more effective in improving MMO post-treatment. A significant difference in MMO was observed at the one-week follow-up, with the ultrasound therapy group showing a larger improvement than the cryotherapy group, the mean difference is 0.99, and the confidence interval (0.86 to 1.12) is also above zero**.** This indicates that ultrasound therapy continues to provide superior MMO recovery compared to cryotherapy even after the treatment period **(Table 3).**

Ultrasound therapy appears to be more effective than cryotherapy in improving maximum mouth opening (MMO) in patients with TMJ dysfunction after surgical tooth extraction, both immediately after treatment and at one-week follow-up.

Table (3): MMO comparison between groups at 3 assessment points

MMO (Mean ±SD)			
Items	Pre-assessment	Post-treatment	Follow-up after one week
Cryotherapy group (n=20)	1.80 ±0.41	2.39 ±0.43	2.66 ±0.43
Ultrasound group (n=20)	1.85 ±0.42	3.23 ±0.45	3.65 ±0.42
Change (MD)	0.05	0.84	0.99
95% CI	-0.26 – 0.36	0.71 – 0.97	0.86 – 1.12
F-value	0.005	15.847	20.494
P-value	0.942	0.0001*	0.0001*
Significance	NS	S	S

Data are expressed as mean ±standard deviation
MD: Mean difference (change) 95% CI: confidence interval
P-value: probability value S: significant
* Significant (P<0.05) NS: non-significant

3. Visual analogue scale (VAS)

3.1. VAS within group comparisons:

In the cryotherapy group, the evaluation showed a significant reduction in VAS scores from pre-treatment to post-treatment, with a very

low p-value (P=0.0001), indicating a highly significant result, the change in VAS scores was 4.60, with an overall improvement of 51.69%. Similarly, there was a significant reduction in VAS scores from pre-treatment to one-week follow-up, with a highly significant p-value (P=0.0001), the observed change was 7.40, with an improvement of 83.15%. At the one-week follow-up, there was a continued significant reduction in VAS scores compared to post-treatment (P=0.0001), the VAS score reduced by 2.80, with a percentage improvement of 65.12%.

In the ultrasound group, the statistical analysis indicated a significant reduction in VAS scores from pre-treatment to post-treatment, with a very low p-value (P=0.0001), highlighting the effectiveness of the treatment the VAS score decreased by 5.70 units, reflecting a 62.98% improvement from pre-treatment to post-treatment. A significant decrease in VAS scores was also observed from pre-treatment to the one-week follow-up, with the same p-value (P=0.0001), suggesting a lasting effect of ultrasound therapy, the VAS score decreased by 8.70 units, leading to a 96.13% improvement from pre-treatment to one-week follow-up. There was a significant reduction in VAS scores between post-treatment and the one-week follow-up, with a highly significant p-value (P=0.0001), the VAS score decreased by 3.00 units, reflecting an 89.55% improvement from post-treatment to one-week follow-up **(Table 4).**

Table (4): VAS within group comparisons

Items	Cryotherapy group (n=20)	Ultrasound group (n=20)
VAS among 3 assessment points within each group		
Pre-assessment	8.90 ±1.11	9.05 ±0.99
Post-treatment	4.30 ±1.26	3.35 ±1.08
Follow-up after one week	1.50 ±0.48	0.35 ±0.15
F-value	25.666	61.873
P-value	0.0001*	0.0001*
Significance	S	S
VAS between pre-assessment and at post-treatment within each group		
Pre-assessment	8.90 ±1.11	9.05 ±0.99
Post-treatment	4.30 ±1.26	3.35 ±1.08
Change (MD)	4.60	5.70
95% CI	3.80 – 5.39	4.90 – 6.49
Improvement %	51.69%	62.98%
F-value	15.006	21.179
P-value	0.0001*	0.0001*
Significance	S	S
VAS between pre-assessment and follow-up within each group		
Pre-assessment	8.90 ±1.11	9.05 ±0.99
Follow-up after one week	1.50 ±0.48	0.35 ±0.15
Change (MD)	7.40	8.70
95% CI	6.60 – 8.19	7.90 – 9.49
Improvement %	83.15%	96.13%
F-value	19.026	31.761
P-value	0.0001*	0.0001*
Significance	S	S

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VAS between post-treatment and follow-up within each group		
Post-treatment	4.30 ±1.26	3.35 ±1.08
Follow-up after one week	1.50 ±0.48	0.35 ±0.15
Change (MD)	2.80	3.00
95% CI	2.00 – 3.59	2.20 – 3.79
Improvement %	65.12%	89.55%
F-value	16.894	20.563
P-value	0.0001*	0.0001*
Significance	S	S

Data are expressed as mean ±standard deviation MD: Mean difference (change) 95% CI: confidence interval
P-value: probability value S: significant * Significant (P<0.05) NS: non-significant

3.2. VAS between group comparisons:

The results of the pairwise comparisons test evaluating the impact of cryotherapy and ultrasound therapy on VAS scores showed that there was no significant difference between the two groups at the pre-assessment stage with mean difference between the two groups or time points is 0.15, with a 95% confidence interval ranging from -0.50 to 0.80. A significant difference was observed between the two groups post-treatment with mean difference is 0.95, and the 95% confidence interval ranges from 0.29 to 1.60, indicating that ultrasound therapy resulted in a greater reduction in VAS scores and more effective pain relief compared to cryotherapy. A significant difference was again found between the groups at the one-week follow-up with mean difference is 1.15, and the confidence interval ranging from 0.49 to 1.80 indicating that ultrasound therapy continued to show a significantly greater reduction in pain, with much lower VAS scores than those in the cryotherapy group **(Table 5).**

These results suggest that ultrasound therapy not only provided superior immediate pain relief but also resulted in more lasting benefits at one week after treatment compared to cryotherapy.

Table (5): VAS comparison between groups at 3 assessment points

VAS (Mean ±SD)			
Items	Pre-assessment	Post-treatment	Follow-up after one week
Cryotherapy group (n=20)	8.90 ±1.11	4.30 ±1.26	1.50 ±0.48
Ultrasound group (n=20)	9.05 ±0.99	3.35 ±1.08	0.35 ±0.15
Change (MD)	0.15	0.95	1.15
95% CI	-0.50 – 0.80	0.29 – 1.60	0.49 – 1.80
F-value	0.208	8.361	12.252
P-value	0.649	0.005*	0.001*
Significance	NS	S	S

Data are expressed as mean ±standard deviation
MD: Mean difference (change) 95% CI: confidence interval
P-value: probability value S: significant
* Significant (P<0.05) NS: non-significant

DISCUSSION

This randomized clinical trial investigated the efficacy of adding cryotherapy or ultrasound to traditional physiotherapy program on maximum mouth opening and pain in patients with TMJ dysfunction after surgical tooth extraction.

The current study hypothesized that cryotherapy and ultrasound may have an effect on TMJ dysfunction after surgical tooth extraction in patients between 30 and 60 years. The results of the current study showed that there was a significant difference (P<0.05) between the cryotherapy group and the ultrasound group in mean ±SD values of MMO and VAS (P=0.001) at post-treatment and at follow-up after one week from treatment. This significant increase in MMO and significant decrease in

pain were favorable in patients with TMJ dysfunction who had received ultrasound therapy group than patients who had received cryotherapy. Ultrasound offers a more effective and longer-lasting treatment option for improving mouth opening and reducing pain compared to cryotherapy, which can influence clinical decision-making in treating similar conditions.

The symptoms of TMD include restricted jaw movement, discomfort in the chewing muscles and TMJ, sounds from the joint (such as clicking, popping, or crepitus), myofascial pain, and various functional impairments. It has been indicated that the surgical extraction of first premolars may affect jaw movement and could be linked to disorders of the temporomandibular joint [7, 26]. In the current study we used the continuous ultrasound for thermal effect through the healing properties that primarily come from the absorption of mechanical energy and the generation of heat within the tissues, also we used the cryotherapy in the form of ice cubes in slow circular movements to reduce pain, stiffness of TMJ and improvement of its mobility.

The biophysical non-thermal effects of ultrasound are often understood as a combination of factors: when sound waves propagate through a medium, they cause molecules to vibrate, which may influence the exchange of fluids and movement within tissues. Cavitation occurs at therapeutic ultrasound levels, leading to the formation of gas-filled cavities in tissues or fluids that require 1000 cycles to reach their maximum size. Acoustic streaming, occurring when fluids swirl at a small scale near a vibrating structure, can alter membrane permeability and diffusion rates, impacting protein synthesis and physiological secretion [27].

The ultrasound therapy in this study used the principles of cavitation and acoustic streaming. This microstreaming enhances blood circulation and membrane permeability, helping to eliminate harmful metabolites and accumulated chemical mediators, which in turn alleviates discomfort in the nerve endings [28]. In the current study, pain was evaluated using VAS and P values were statistically significant at post-treatment and at follow-up after one week from ultrasound therapy (62.98 and 96.13%) respectively.

Ultrasound waves are produced through a piezoelectric effect caused by the vibrations of crystals within the probe. Its healing properties primarily come from the absorption of mechanical energy and the generation of heat within the tissues. The thermal effects of ultrasound lead to muscle relaxation and enhance local blood circulation, promoting tissue repair and decreasing inflammation [29]. The thermal effect and the absorption of mechanical energy by using ultrasound that was conducted by the current study revealed a significant difference ($P<0.05$) in the results of MMO using Boley Gauge Caliper at post-treatment and at follow-up after one week from the treatment of ultrasound (74.59 and 97.30%) respectively.

These findings were supported by the study of Rao, K. et al.[28], in this study it was observed that postoperative pain was significantly reduced, trismus notably improved with low-intensity pulsed ultrasound in the patients and can be used as an adjunctive method in routine management of post-surgical morbidities. However, they focused on impacted third molar surgery and used pulsed ultrasound than the current study that included patients with different types of surgical tooth extraction and used continuous type of ultrasound therapy.

The key principles of cryotherapy focus on quickly cooling, slowly warming, and freezing multiple times to enhance tissue damage. Cryotherapy-induced vasoconstriction reduces oxygen consumption, tissue metabolism, inflammation, and muscle spasms. This leads to a localized anesthesia effect referred to as cold-induced neuropraxia [6]. In the present study, the results of using cryotherapy supported the findings of reduction in TMJ stiffness caused by muscle spasm and an increase in mandibular mobility, and there was a significant difference ($P<0.05$) in mean values of MMO ($P=0.001$) at post-treatment and at follow-up after one week from treatment (32.78 and 47.78%) respectively.

Ice therapy is an easy treatment method commonly utilized by different practitioners to alleviate postoperative symptoms like pain and

swelling. The positive impacts of cold therapy are linked to various physiological mechanisms, including slowing down tissue metabolism by reducing enzyme activities, constricting blood vessels to lower blood flow, preventing blood leakage into nearby tissues, diminishing inflammation and swelling, and reducing nerve conduction [30-32]. In the present study, the results of cryotherapy in reducing pain by the impact of vasoconstriction and reduced conductivity of the nerves were statistically significant (P<0.05) in mean values of MMO (P=0.001) at post-treatment and at follow-up after one week from treatment (51.69 and 83.15%) respectively.

John SS. et, al. [6] compared the effect of cryotherapy and Low-Level Laser Therapy in pain control and wound healing following an orthodontic tooth extraction in the first seven days. They found that the Pain scores were lesser for the cryotherapy group generally as compared to that of the LLLT group on all days, implying the analgesic effect of cryotherapy was lesser than LLLT, however the difference was not significant (p > 0.05). The current study compared the effect of cryotherapy and ultrasound therapy in reducing pain following surgical tooth extraction and showed that cryotherapy is effective in reducing pain according to VAS scores but its results was favorable in ultrasound therapy group than cryotherapy group. The results of two studies implies that using of these modalities may have superior effect on cryotherapy in pain reduction for patients with TMD after surgical tooth extraction.

A study by Kjærgaard Larsen, M. et al. [33] studied the use of cryotherapy after surgical removal of mandibular third molars and showed that the therapeutic effect of 30 minutes of continuous cryotherapy following surgical removal of mandibular third molars seem to be negligible either for the outcomes of pain (VAS) or MMO. They suggested that during continuous cryotherapy with a gel pack, the temperature will not be held constant during the treatment period. The initial temperature will be low, and the end temperature will be warmer. In addition, the thickness of the subcutaneous adipose tissue may also influence the therapeutic effect of cryotherapy. In the current study intermittent cryotherapy for short period therefore appears to be more effective on postoperative pain compared with continuous cryotherapy.

CONCLUSION

Both interventions appear to be effective in improving MMO and pain in patients with TMJ dysfunction after surgical tooth extraction, but ultrasound therapy not only provided superior immediate improvement but also resulted in more lasting benefits at one week after treatment compared to cryotherapy. Adding ultrasound therapy to traditional physiotherapy program is crucial for the management of TMJ dysfunction after surgical tooth extraction.

Scientific Responsibility Statement:

The authors confirm that they contributed to this study by collecting, analyzing, and interpreting data, as well as writing, preparing, and approving the final article draft.

Human rights statement:

Every procedure used in this study complied with the Helsinki Declaration (1964) and its subsequent modifications, as well as similar ethical norms, and the guidelines of the organizational and/or national research committee.

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Conflict of interest:

The authors declare no conflicts of interest.

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