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ULTRAZVUČNA TERAPIJA U ZBRINJAVANJU POREMEĆAJA TEMPOROMANDIBULARNOG ZGLOBA

ULTRASOUND THERAPY IN THE MANAGEMENT OF TEMPOROMANDIBULAR JOINT DISORDERS

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Sažetak

Uvod: *Poremećaji temporomandibularnog zgloba (TMP) su zajednički naziv za poremećaje koji pogađaju temporomandibularni zglob (TMZ), mastikatorne mišiće i njihove okolne strukture. Etiologija TMP-a je složena, a njihovo lečenje uključuje različite invazivne i neinvazivne metode. Sve veći trend neinvazivnih, nefarmakoloških intervencija za lečenje bola u TMZ-u doveo je do razvoja modaliteta u okviru fizikalne terapije. Ultrazvuk je elektrofizički modalitet lečenja, koji se koristi u lečenju TMP-a.*
Cilj *ovog rada je pružanje uvida u modalitete lečenja zasnovane na ultrazvuku, koji se koriste za efikasno lečenje TMP-a.*
Materjali i metode: *Pretraga elektronske baze podataka izvršena je u Google Scholar-u i PubMed-u, i to korišćenjem sledećih termina: „terapija ultrazvukom"; „terapeutski ultrazvuk"; „poremećaji temporomandibularnog zgloba".*
Rezultat*i dobijeni pretraživanjem baze podataka pregledani su i uključeni u ovaj pregledni rad. Ovde su razmatrane najčešće korišćene terapijske ultrazvučne metode u lečenju poremećaja temporomandibularnog zgloba, zajedno sa protokolima lečenja, prednostima, ograničenjima i drugim faktorima, koje treba uzeti u obzir kako bi ishod lečenia bio efikasan.*
Zakliučak*: U bliskoi budućnosti mogu se razviti različiti novi terapijski modaliteti TMZ zasnovani na ultrazvuku.*

Ključne reči: *fizikalna terapija, fonoforeza, ultrazvučna terapija, poremećaji temporomandibularnog zgloba*

Abstract

Introduction: *Temporomandibular joint disorder (TMD) is a collective term given to the disorders affecting the Temporomandibular joint(TMJ), masticatory muscles and their related structures. The aetiology of TMD is complex and their management includes various invasive and non-invasive methods. The increasing trend in non-invasive, non-pharmacological interventions for the management of TMJ pain has led to the development of modalities of physical therapy. Ultrasound is an electrophysical treatment modality used in the management of TMD.*
The aim *of this study is to provide an insight into ultrasound based treatment modalities used for the effective management of TMD.*
Materials and methods:*Electronic database search was carried out in Google Scholar and PubMedusing the search terms "ultrasound therapy", "therapeutic ultrasound" and "temporomandibular joint disorders".*
The results *obtained from the database search were screened and included for the review. Commonly used therapeutic ultrasound methods in the management of temporomandibular joint disorders with the treatment protocols, advantages, limitations and other factors to be considered for an effective treatment outcome is discussed in the present review.*
Conclusion: *Various new ultrasound-based TMJ therapeutic modalities may be developed in the near future.*

Key words: *physical therapy, phonophoresis, ultrasonic therapy, temporomandibularjoint disorders*

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Uvod

Temporomandibularni zglob (TMZ) je jedan od složenih sinovijalnih zglobova u ljudskom telu. Poremećaji koji uključuju TMZ, mastikatorne mišiće i njihove okolne strukture zajedno se nazivaju poremećajima temporomandibularnog zgloba (TMP)[1]. Ova grupa poremećaja predstavlja jedan od najčešćih uzroka orofacijalnog bola. Etiologija TMP-a je složena, a njihovo lečenje uključuje različite invazivne i neinvazivne metode. Sve veći trend traganja za neinvazivnim, nefarmakološkim intervencijama za lečenje bola u TMZ-u doveo je do razvoja modaliteta fizikalne terapije. Različiti elektrofizički terapijski modaliteti koji se trenutno koriste za ublažavanje bolova povezanih sa TMP-om uključuju ultrazvuk (UZ), mikrotalase, transkutanu električnu stimulaciju nerva i lasersku terapiju niskog nivoa[2]. Ultrazvuk je dobro uspostavljen modalitet lečenja u opštoj fizioterapiji mišićno-skeletnog bola[3]. Postoje različiti oblici terapeutskog ultrazvuka, koji se koriste u lečenju TMP-a. Cilj ovog preglednog rada je da pruži kratak opis različitih modaliteta lečenja zasnovanih na ultrazvučnoj terapiji TMP-a. Pretražili smo elektronske baze podataka Google Scholar i PubMed koristeći termine „ultrazvučna terapija", „terapeutski ultrazvuk" i „poremećaji temporo-mandibularnog zgloba". Rezultati dobijeni pretraživanjem baze podataka pregledani su i obuhvaćeni ovim preglednim radom.

Terapeutski ultrazvuk

Ultrazvuk se odnosi na zvučne talase koji osciliraju sa frekvencijom većom od 20.000 ciklusa u sekundi – herc (Hz). Nazivaju se i visokofrekventnim talasima. Ultrazvuk (UZ) je dobro poznati imidžing i terapeutski modalitet, koji je učvrstio svoju primenu u oblasti medicine. Terapeutski ultrazvuk može se definisati kao upotreba ultrazvučnih talasa za lečenje obolelih ili povređenih organa ili telesnih struktura. Terapeutski UZ radi na frekvencijskom opsegu od 0,7 MHz do 3,3 MHz[3,4]. Primena terapeutskog ultrazvuka (Th UZ) u medicini datira od ranih tridesetih godina dvadesetog veka. Početne primene bile su zasnovane na mehanizmu zagrevanja tkiva. Ogroman napredak u nauci i tehnologiji doveo je do raznih drugih primena terapijskog ultrazvuka, uključujući lečenje Menierove bolesti za uništavanje vestibularnog nerva i korišćenje fokusiranog ultrazvuka u lečenju Parkinsonove bolesti lokalizovanim uništavanjem tkiva u mozgu.

Introduction

Temporomandibular joint (TMJ) is one of the complex synovial joints in the human body. Disorders involving the TMJ, masticatory muscles and their related structures are grouped together as Temporomandibular joint disorder (TMD)[1]. These group of disorders remain one of the most common causes of orofacial pain. The aetiology of TMD is complex and its management includes various invasive and non-invasive methods. The increasing trend in the need of non-invasive, non-pharmacological interventions for the management of TMJ pain hasled to the development of modalities of physical therapy. Various electrophysical therapeutic modalities that are currently used in relieving pain associated with TMD include ultrasound (US), microwaves, transcutaneous electrical nerve stimulation and low-level laser therapy[2]. Ultrasound is a well-established treatment modality in general physiotherapy for musculoskeletal pain[3]. There are various forms of therapeutic ultrasound that are being used in the management of TMD. The aim of this review is to provide a brief description of various ultrasound based treatment modalities for the management of TMD. We conducted an electronic database search in Google Scholar and PubMed using the search terms "ultrasound therapy", "therapeutic ultrasound" and "temporo-mandibular joint disorder". The results obtained from the database search were screened and included for the review.

Therapeutic Ultrasound

Ultrasound refers to sound wavest hat oscillatewith a frequency greater than 20,000 cycles per second/Hertz (Hz). They are also called high frequency waves. Ultrasound (US) is a well-knownimaging and therapeutic modality that has established its applications in the field of medicine. Therapeutic ultrasound can be defined as the use of ultrasonic waves for the treatment of diseased or injured organs or bodily structures. Therapeutic US works on a frequency range of 0.7 MHz to 3.3 MHz[3,4]. Applications of therapeutic ultrasound (Th Us) in medicine dates back to the early 1930s. The initial applications were based on the mechanism of tissue heating.

Tremendous advancements in science and technology led to various other application of therapeutic ultrasound including the

Kasnije, 1970. godine, terapeutski ultrazvuk stekao je popularnost u oblasti fizioterapije. Terapijski ultrazvuk se u poslednje vreme koristi i u neurohirurgiji i onkologiji. Osim lečenja mišićno-skeletnog bola, druge opšte terapeutske primene ultrazvuka u medicini uključuju upotrebu u cilju zarastanja preloma, oseointegracije, zarastanja povreda kože i mekih tkiva, terapija karcinoma i urooloških primena[5,6].

Mehanizam i biofizički efekti terapijskog ultrazvuka

Kada je ultrazvuk fokusiran na određeno mesto u telu, UZ talasi prodiru u tkiva i proizvode biofizičke efekte. Biofizički efekti ultrazvuka mogu se globalno klasifikovati na termičke i netermičke efekte[6]. Prodor UZ u tkiva izaziva lokalno stvaranje toplote. Apsorpcija i penetracija ultrazvuka uslovljene su u velikoj meri, sadržajem proteina u tkivu (Figura 1). Tkiva sa nižim sadržajem vode i većim sadržajem proteina pokazaće veću apsorpciju ultrazvuka. Poznato je da tkiva sa visokim sadržajem kolagena, kao što su ligamenti, fascije i kapsularni deo zglobova, pokazuju maksimalnu apsorpciju UZ talasa[7,8]. Ultrazvučni talasi izazivaju vibracije makromolekula u tkivu, što dovodi do zagrevanja tkiva. Ova toplotna energija će dovesti do lokalne vazodilatacije, što nadalje dovodi do povećanog ćelijskog metabolizma. Da bi se postigao značajan termički efekat, temperatura tkiva mora se podići na 40 °C do 45 °C u trajanju od minimalno pet minuta. Ovo termičko svojstvo može dovesti do ublažavanja bolova i smanjenja ukočenosti zglobova[9].

Netermički efekti ultrazvuka zasnovani su na principima kavitacije i akustičnog strujanja. Ultrazvučni talasi vrše određenu silu na gasove mikrookoline prisutne u tkivnim tečnostima. Ova sila dovodi do razređivanja i kompresije gasa, što rezultira stvaranjem mikroskopskih gasnih mehurića u tkivnoj tečnosti. Ovo svojstvo naziva se kavitacija. Mehurići gasa mogu biti podvrgnuti brzim promenama pritiska zbog nestabilne kavitacije i mogu izazvati oštećenje ćelija; stoga je potreban oprez kada je ultrazvučna terapija fokusirana na regione u blizini šupljina ispunjenih vazduhom[10].

Sposobnost fizičkih sila koje vrše ultrazvučni talasi kako bi izazvali pomeranje jona i malih molekula naziva se akustičnim strujanjem.

treatment of Meniere's disease for the destruction of the vestibular nerve, the use of focused ultrasound in the management of Parkinson's disease by localized tissue destruction in the brain. Later in 1970, therapeutic ultrasound gained popularity in the field of physiotherapy. Recently, therapeutic ultrasoundis being used inneurosurgery and oncology as well. Apart from the management of musculoskeletal pain, othe rgeneral therapeutic applications of ultrasound in medicine include fracture healing, osseointegration, healing of skin and soft tissue injuries, cancer therapy and urological applications[5,6].

Mechanism and Biophysical effects of Therapeutic Ultrasound

When ultrasound is focused on a particular site of the body, the US waves penetrate the tissues and produce biophysical effects. The biophysical effects of ultrasound can be broadly classified into thermal and nonthermal effects[6]. The penetration of US into the tissues causes local heat generation. The absorption and penetration of ultrasound differs widely based on the protein content of the tissue (Figure 1). Tissues with a lower water content and a higher protein content will show higher absorption of ultrasound.Tissues with high collagen content such as ligaments, fascia and capsular part of the joints are known to exhibit maximum absorption[7,8].The ultrasound waves cause vibration of macromolecules in the tissue resulting in the heating of the tissues. This thermal energy induces local vasodilation, resulting in increased cellular metabolism. To achieve a significant thermal effect the temperature of the tissue has to be raised upto 40−45°C for a minimum duration of 5 minutes. This thermal property can provide pain relief and decrease in joint stiffness[9].

The non-thermal effects of ultrasound are based on the principles of cavitation and acoustic streaming. The ultrasound waves exert certain force on the microenvironmental gases present within the tissue fluids. This force results in rare faction and compression of gas resulting in formation of microscopic gas bubbles in the tissue fluid. This property is termed as cavitation. The gas bubbles can undergo rapid pressure changes due to unstable cavitation and may cause cell injury. Therefore, caution needs to be exercised when ultrasound therapy is focused in regions near air-filled cavities[10].

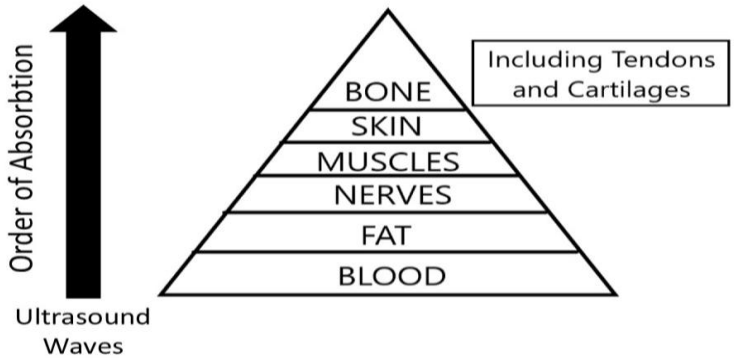

Figura 1. Redosled ultrazvučne apsorpcije
***Figure 1*:** Order of ultrasonic absorption

Mehanički pritisak koji vrši akustična struja dovodi do jednosmernog kretanja tečnosti oko ćelijskih membrana i može promeniti permeabilnost ćelije. Ovo svojstvo akustičnog strujanja ultrazvuka ima različite biomedicinske primene[10,11].

Toplotni efekti ultrazvuka mogu dovesti do modifikacije svojstava kolagena povećavajući rastegljivost, odnosno dovode do mobilizacije zglobova i istezanja[12]. Neto rezultat ultrazvuka na ćelijskom nivou uključuje povećanje sinteze proteina, degranulaciju mastocita, proizvodnju faktora rasta, unos kalcijuma, promene u jonskim kanalima i pokretljivost fibro-blasta. Poznato je da ove ćelijske promene imaju analgetički efekat, kao i da podstiču popravku tkiva uzrokovanu upalom[6].

Tehnički parametri

Terapeutski ultrazvuk je modalitet čiji odgovor zavisi od doze[13]. Tehnički parametri ultrazvučne opreme mogu se definisati kao tehnička podešavanja za određeni cilj lečenja i uključuju intenzitet, učestalost, radni ciklus i vreme tretmana. Svi ovi parametri imaju direktan uticaj na ishod lečenja[14]. Terapeutski ultrazvuk se na osnovu frekvencije može klasifikovati na ultrazvuk velike i ultrazvuk male snage. Primene ultrazvuka velike snage uključuju fokusirani ultrazvuk visokog intenziteta (VIFU) za hirurške ablacije i litotripsiju, dok ultrazvuk male snage uključuje terapiju bola i zarastanje, sonoforezu i sonoporaciju[4,15].

Sredstvo za spajanje potrebno je da prenese UZ talase iz sonde u tkivo, pošto vazduh prisutan između njih reflektuje UZ talase.

The ability of the physical forces exerted by theultrasound wavesto cause displacement of ions and small molecules is termed acoustic streaming. The mechanical pressure exerted by the acoustic streaming results in unidirectional movement of fluid around cell membranes and may alter cell permeability. This property of acoustic streaming of ultrasound has various biomedical applications[10,11].

The thermal effects of ultrasound can lead to modifications of the collagen properties that increase extensibility, thus promoting joint mobilization and stretching[12].The net result of ultrasound at the cellularlevel includes increase in protein synthesis, mast cell degranulation, growth factor production, uptake of calcium, alterations in the ion channels and fibro-blast mobility. These cellular changes are known to have analgesic effect and also to promotethe tissue repaircaused due to inflammation[6].

Technical Parameters

Therapeutic ultrasound is a modality that produces dose based response[13]. The technical parameters of the ultrasound equipment can be defined as the technical settings for a specific treatment goal and include, intensity, frequency, duty cycle, treatment time. All these parameters have a direct effect on the treatment outcome[14]. Therapeutic ultrasound can be broadly classified as high power and low power ultrasound based on the frequency. Applications of high power US include high intensity focused US (HIFU) for surgical ablations and lithotripsy, while low power US includes pain therapy and healing, sonophoresis and sonoporation[4,15].

A coupling agent is required to transmit the US waves from the transducer into the tissue, as air present between them reflects the US waves.

Ova sredstva za spajanje treba da imaju nizak koeficijent apsorpcije, a njihova akustična impedansa treba da bude slična tretiranom tkivu ili viša od njega. Najviše korišćena sredstva za spajanje u tehnici direktnog kontakta jesu gelovi, mineralna ulja i beli vazelin, dok se u tehnici potapanja koristi voda[16]. Frekvencija je jedan od najvažnijih tehničkih parametara i bira se na osnovu dubine tkiva koje se tretira. Penetracija ultrazvuka u različite dubine može se opisati u smislu dubine poluvrednosti. Dubina poluvrednosti može se definisati kao dubina ili udaljenost u tkivu na kojoj se 50% ultrazvučne energije raspršuje. Prema podacima iz literature, približna dubina poluvrednosti od 1 MHz je oko 2,3 cm, dok je kod kontinuiranog ultrazvuka od 3 MHz oko 0,8 cm. Dakle, 3MHz koriste se za površinska tkiva do dubine od 2 cm, a 1 MHz koristi se za dublja tkiva do dubine od 5 cm[17-19]. Postoje dva režima rada terapeutskog ultrazvuka – kontinuirani i pulsni režim. Kontinualni režim emituje tok ultrazvučnih talasa kao kontinuirani, dok pulsni režim emituje UZ talase u redovnim intervalima u zavisnosti od radnog ciklusa. U tipičnom odnosu impulsa 1 : 1, mašina nudi izlaz za 2 ms, nakon čega sledе 2 ms odmora. Impulsna UZ terapija preporučuje se za akutni bol, a kontinuirana UZ za hronični bol. Slično, niski intenziteti koriste se za akutni bol, a veći intenzitet za terapiju hroničnog bola[9]. Prema Ilteru i sar.[20], kontinuirana UZ terapija je efikasnija u smanjenju bola od pulsne UZ terapije kod pacijenata sa miofascijalnim bolom. Slično, niski intenziteti koriste se za akutni bol, a veći intenzitet za terapiju hroničnog bola[9]. Prema Ilteru i sar.[20], kontinuirana UZ terapija je efikasnija u smanjenju bola od pulsne UZ terapije kod pacijenata sa miofascijalnim bolom.

Obični terapijski ultrazvuk

Terapijski ultrazvuk koristi se kod poremećaja temporomandibularnog zgloba za ublažavanje muskuloskeletnog bola, za smanjenje upale i za obnavljanje funkcije zgloba. Terapijski UZ primenjuje se pomoću sonde pogodne veličine, koja se plasira na ciljnu regiju u sporim kružnim pokretima. Grej i sar.[21] sproveli su studiju kako bi uporedili efekte kratkotalasne dijatermije, ultrazvuka niskog intenziteta i laserske terapije niskog nivoa (LLNT) kod pacijenata sa disfunkcijom TMZ-a.

These coupling agents should have as a low-absorption coefficient and their acoustic impedance should be similar or higher than the treated tissue. The most-used coupling agents in the direct-contact technique are gels, mineral oils, and white petrolatum jelly, while water is used in the immersion technique[16]. Frequency is one of the most important technical parameters and it is selected based on the depth of the tissue to be treated. The penetration of ultrasound to varied depth can be described in terms of the half-value depth.

The half-value depth can be defined as the depth or distance in the tissue at which 50% of the ultrasound energy gets dissipated. According to the literature evidences, the approximatehalf-value depth of 1MHz is about 2.3 cm and 3-MHz continuous ultrasound is about 0.8 cm. Hence, 3MHz is used for superficial tissues up to 2 cm deep and 1MHz is used for deeper tissues up to 5 cm deep[17-19]. There are two operating modes of therapeutic ultrasound such as continuous and pulsed mode. The continuous mode emits as continuous stream of ultrasound waves while the pulsed mode emits US waves at regular intervals depending on the duty cycle. In a typical 1:1 pulse ratio, the machine offers an output for 2 ms followed by 2 ms rest. Pulsed US therapy is recommended for acute pain and continuous US is recommended for chronic pain. Similarly, low intensities are used for acute pain and higher intensities are used for chronic pain[9]. According to Ilter et al[20] continuous US therapy is more effective in reducing pain than pulsed US therapy, in patients with myofascial pain.

Plain Therapeutic Ultrasound

Therapeutic ultrasound is used in temporomandibular join disorders to relieve musculoskeletal pain, to reduce inflammation, and to restore the joint function. Therapeutic US is applied by a transducer of convenient size based on the target area in slow circular motions. Gray et al[21] conducted a study to compare the effects of short-wave diathermy, low intensity ultrasound and low level laser therapy (LLLT) in patients with TMJ dysfunction.

They found no significant difference in comparative efficacy among the four modalities, but all the four modalities were equally effective in improving the clinical signs and symptoms.

Nisu našli značajnu razliku u komparativnoj efikasnosti između četiri modaliteta, ali su sva četiri modaliteta bila podjednako efikasna u poboljšanju kliničkih znakova i simptoma.

Rai S i sar.[22] sproveli su komparativnu studiju kako bi utvrdili efikasnost terapijskog ultrazvuka i TENS-a u lečenju miofascijalnog bola kod pacijenata koji imaju TMP i otkrili su da je terapijski ultrazvuk efikasniji u smanjenju skora vizuelne analogne skale (VAS) mišićnog bola, smetnjama u svakodnevnom životu i utiska masaže. Slično tome, Kirupa i sar.[23] otkrili su da je ultrazvučna terapija kod TMP-a efikasnija u smanjenju bola od TENS-a. Elgohari i sar.[24] upoređivali su efekte ultrazvuka niskog intenziteta, tradicionalne terapije vežbanjem, kombinacije LLLT i TET na bol i trizmus TMZ-a kod pacijenata koji se oporavljaju od karcinoma glave i vrata (KGV); otkrili su da su ultrazvuk i tradicionalna terapija vežbanjem efikasniji u smanjenju bolova u TMZ-u i trizmusu nakon HKGV-a. Studija Handa R i sar.[25] pokazala je da UZ masažna terapija služi kao moćan i nezavisan terapeutski modalitet kod TMP-a. Parametri koji se tiču tretmana, broja tretmana i intervala između svake sesije uveliko se razlikuju od studije do studije. Parametri tretmana za lečenje TMP-a korišćeni u studijama koje su uključene u ovaj pregledni rad prikazuju se u Tabeli 1.

Fonoforeza

Fonoforeza predstavlja upotrebu terapijskog ultrazvuka za uvođenje farmakoloških agenasa kroz netaknutu kožu u potkožno tkivo. Obično se koriste antiinflamatorni ili analgetski lekovi[26]. Fonoforeza može povećati apsorpciju kože i prodiranje lokalnih lekova u dublja tkiva. Terapeutski efekti lokalno primenjenih lekova zavise od različitih faktora, kao što su brzina, količina, penetracija leka i dubina kože[27]. Vijaialakshmi i sar.[28] sproveli su kliničko ispitivanje kako bi procenili efikasnost fonoforeze aceklofenak gela u lečenju TMP-a. Njihovi rezultati pokazali su značajno povećanje srednjeg maksimalnog otvaranja usta, lateralne ekskurzije i smanjenje skorova VAS-a, Helkimo anamnestičkog indeksa i indeksa kliničke disfunkcije u grupi fonoforeze aceklofenaka u poređenju sa lokalnom primenom ovog leka. Prema Fernandez-Cuadrosu i sar.[28], fonoforeza diklofenaka može delovati kao efikasna fizikalna terapija za lečenje TMP-a.

Rai S. et al.[22] conducted a comparative study to determine the efficacy of therapeutic Ultrasound and TENS in the management of myofascial pain in TMD patients. They found therapeutic ultrasound to be more effective in reducing the Visual analogue scale (VAS) score of muscle pain, impediment to daily life, and massage impression. Similarly, Kirupa et al[23] also found ultrasound therapy to be more efficient in reducing pain in TMD than TENS. Elgohary et al[24] compared the effects of low intensity ultrasound, traditional exercise therapy, combination of LLLT and TET on TMJ pain and trismus in patients recovering from head and neck cancer (HNC). They found ultrasound and traditional exercise therapy to be more effective reducing TMJ pain and trismus following HNC.Handa R. et al.[25] study stated that US massage therapy serves as a potent and independent therapeutic modality in TMDs. The treatment parameters, number of treatment sessions and the interval between each sessiondiffers widely among various studies. Treatment parameters used in the studies included in the present review for the management of TMD sare summarized in Table 1.

Phonophoresis

Use of therapeutic ultrasound to introduce pharmacologic agents through intact skin into the subcutaneous tissues is phonophoresis. Usually anti-inflammatory or analgesic drugs are used[26]. Phonophoresis can increase the skin absorption and penetration of the topical medications to the deeper tissues. Therapeutic effects of topically applied drugs depend on various factors such as rate, amount, drug penetration, depth of the skin[27]. Vijayalakshmi et al[28] conducted a clinical trial to assess the effectiveness of aceclofenac gel phonophoresis in the management of TMD. Their results showed significant increase in mean maximum mouth opening, lateral excursion and a reduction in scores of VAS, Helkimo anamnestic, and clinical dysfunction index in aceclofenac phonophoresis group as compared to the topical application of acelcofenac. According to Fernandez-Cuadros. et al.[28] diclofenac phonophoresis can acts as an effective physical therapy for the management of TMD. Ramakrishnan. et al.[30] conducted a study to compare the efficacy of aceclofenac phonophoresis and plain ultrasound therapy in patients with TMD.

Ramakrishnan i sar.[30] sproveli su studiju u cilju poređenja efikasnosti fonoforeze aceklofenaka i obične ultrazvučne terapije kod pacijenata sa TMP-om. Otkrili su da je fonoforeza aceklofenaka unekoliko bolja od terapije običnim ultrazvukom.

Poznato je da je fonoforeza sa kortikosteroidima, kao što je lokalno aplikovani hidrokortizon, efikasna u lečenju bola u TMZ-u[31]. Koncentracija i vrsta leka koji se koristi (Tabela 2), kao i trajanje fonoforeze, variraju u zavisnosti od kliničkih zahteva.

They found aceclofenac phonophores is to be slightly superior than Plain ultrasound therapy. Phonophoresis with corticosteroids such as topical hydrocortisone is also known to be effective in management of TMJ pain[31]. The concentration and type of the drug to be used (Table 2) and duration of phonophoresis vary depending on the clinical requirement.

Tabela 1. Terapijski parametri za običnu ultrazvučnu terapiju
Table 1. Treatment parameters for plain ultrasound therapy

Parametri Parameters		**Rai S i sar.[22] (2016) Rai S. et al.[22](**	**Kirupa i sar.[23] (2018) Kirupa et al.[23]**	**Elgohary i sar.[24] (2018) Elgohary et al.[24]**	**Handa i sar.[25] (2018) Handa et al.[25]**
Veličina uzorka (Muškarci i žene) Sample size (males andfemales)		90 (25 muškaraca i 65 žena) (25 males,65 female)	30	60 (33 muškarca i 27 žena) (25 males,65 female)	10 (tri muškarca i sedam žena) (3 males,7 females)
Starost populacije iz studije Age group of study population		20 – 60 godina / years	20 – 40 godina / years	/	18–50 godina years
Režim Mode		/	Kontinuirano/continuous	pulsno pulsed	pulsno (1 : 1) pulsed
Frekvencija Frequency		/	1 i 3 MHz	1 MHz	1 MHz
Doza Dose		/	/	1,0 W/cm^2	/
Trajanje terapije Treatment duration		/	pet minuta 5 minutes	pet minuta 5 minutes	osam minuta 8 minutes
Terapijske sesije Treatment sessions		tri puta svake dve nedelje tokom 12 nedelja / 3 times every 2 weeks for 12 weeks	/	pet puta nedeljno tokom četiri nedelje 5 times/week for 4 weeks	jednom nedeljno tokom četiri nedelje once in a week for 4 weeks
Parametri korišćeni za pristup Parameter used to access		maksimalno otvaranje usta bez bola; subjektivna procena bolova u mišićima pomoću VAS-a; subjektivna procena smetnji u svakodnevnom životu na osnovu VAS-a i otiska masaže maximum mouth opening without pain, subjective evaluation of muscle pain using VAS, subjective evaluation regarding impediment to daily life based on VAS and massage impression	procena bola pomoću VAS-apain assessment by VAS	merenje maksimalnog otvaranja usta, merenje intenziteta bola pomoću VAS-ameasurement of maximum mouth opening, measurement of pain intensity by VAS	procena otvaranja usta i procena bola na osnovu VAS-a assessment of mouth opening and pain assessment based on VAS
VAS rezultati običnom ultrazvučnom terapijom Results of VAS by Plain Ultrasound therapy	**Pre tretmana Pre-treatment**	247,87 ± 26,53	7,32 ± 1,16	7,75 ± 1,41	7,30 ± 1,70
	Posle tretmana Post-treatment	20,87 ± 6,35	3,73 ± 3,96	2,65 ± 1,50*	4,00 ± 2,53

*Kombinacija ultrazvučne terapije niskog intenziteta sa tradicionalnom terapijom vežbanjem.
* Combination of low intensity ultrasound therapy along with traditional exercise therapy

Tabela 2. Terapijski parametri za fonoforezu
Table 2. Treatment parameters for phonophoresis

Parametar Parameter		**Vijayalakshmi i sar.** [28] **(2015) Vijayalakshmi et al.**[28]	**Ramakrishnan i sar.** [30] **(2019) Ramakrishnan et al.**[30]	**Fernandez-Cuadros i sar.** [29] **(2020) Fernandez-Cuadros et al.**[29]**]**	**Sequeira i sar.** [31] **(2020) Sequeira et al.**[31]
Veličina uzorka (Muškarci & Žene) Sample size (males andfemales		60 (23 muškarca i 37 žena) males, females	50	50 (devet muškaraca i 41 žena) (males, females)	20 (jedan muškarac i 19 žena) (males, females)
Starosna grupa Age group		70–80 godina years	/	/	20–50 godina years
Režim Mode		kontinuirano continuous	kontinuirano continuous	kontinuirano continuous	Pulsno pulsed
Frekvencija Frequency		1 MHz	1 MHz	1 MHz	3 MHz
Doza Dose		0.8 W/cm^2 – 1.5 W/cm^2	1.5 W/cm^2	1 W/cm^2	1,5 W/cm^2 – 2,0 W/cm^2
Trajanje terapije Treatment duration		deset minuta minutes	osam minuta minutes	pet minuta minutes	od sedam do deset minuta minutes
Terapijske sesije Treatment sessions		tri puta nedeljno tokom dve nedelje3 times/week for 2 week	tri puta nedeljno tokom dve nedelje3 times/week for 2 weeks	jedna sesija na dan 20 uzastopnih dana1 session/day for 20 consecutive days	sedam dana uzastopno7 consecutive days
Parametri korišćeni za pristup Parameter used to access		procena bola pomoću VAS-a, procena pokreta mandibule, maksimalno aktivno otvaranje usta (AMO), maksimalno pasivno otvaranje usta (PMO), bočni ekskurzivni i protruzivni pokreti vilice (RLE i LLE), procena Helkimo indeksa, procena brzine sedimentacije eritrocita (ESR) pain assessment by VAS, assessment of mandibular movements, maximum active mouth opening(AMO), maximum passive mouth opening(PMO), lateral excursive and protrusive jaw movement(RLE and LLE), Helkimo index assessment, assessment of erythrocyte sedimentation rate(ESR)	nivo VAS-a i C-reaktivnog proteina VAS and C-reactive protein level	otvaranje usta, rastojanje od usana do usana i međuincizivno rastojanjemouth opening, lip to lip distance andinter incisal distance	maksimalno otvaranje usta i intenzitet bola maximum mouth opening andpain intensity
VAS Rezultati fonoforezom Results of VAS by Phonophoresis	**Pre terapije Pre-treatment**	7.57 ± 1.04	6.40	6.67 ± 0.82	9 ± 1.05
	Posle terapije Post-treatment	3.10 ± 2.77	2.12	3.48 ± 0.75	0

Pulsni ultrazvuk niskog intenziteta (PUNI)

PUNI je novi napredak u oblasti terapije zasnovane na ultrazvuku. Ima potencijal da se koristi u lečenju različitih nervnih, skeletnih i mišićnih bolesti. PUNI se odnosi na pulsni UZ sa intenzitetom manjim od 100 mV/cm² za ciljanje obolelog područja[32]. PUNI olakšava prenos relativno male količine energije do ciljnog tkiva, čime se sprečava termičko oštećenje izazvano prekomernim stvaranjem toplote tretiranog područja[33]. Poslednjih godina, PUNI je istraživan kao modalitet lečenja osteoartritisa (OA) TMZ-a zbog svog potencijala za regeneraciju tkiva[34]. Mehaničko preopterećenje kondilarne hrskavice donje vilice izaziva ekspresiju IL-1b, inflamatornog citokina, koji je blisko povezan sa progresijom TMJ-OA[35]. *In vitro* studije Uddina i sar.[36] pokazale su da PUNI može sprečiti destrukciju hrskavice inhibiranjem kataboličkog dejstva IL-1b, a takođe je poznato da stimuliše migraciju, proliferaciju i diferencijaciju hondrocita. Liang i sar.[37] demonstrirali su upotrebu PUNI na pacovima i dokazali da može efikasno inhibirati povredu kondilarne hrskavice izazvane hroničnom deprivacijom sna. Dakle, PUNI može poslužiti kao efikasan neinvazivni modalitet lečenja u lečenju TMZ OA.

Prednosti i mane UZ

Praksa primene ultrazvučne terapije kod poremećaja temporomandibularnog zgloba ima različite prednosti, koje se ogledaju u ekonomičnosti, lakoći tehnike, neinvazivnoj prirodi procedure i sposobnosti da se obezbedi značajno ublažavanje bola[3,4,11]. Ultrazvučna fonoforeza ima dodatnu prednost u smanjenju rizika od oštećenja jetre i bubrega usled eliminacije leka, jer eliminiše potrebu za sistemskim lekovima; takođe, pacijenti je dobro podnose[30]. Rašid i dr. sproveli su nacionalnu anketu među konsultantima za oralnu i maksilofacijalnu hirurgiju Ujedinjenog Kraljevstva (UK); u njoj je 52% konsultanata izjavilo da je ultrazvuk efikasan elektrofizički modalitet u lečenju TMD-a[38]. Jedan od glavnih nedostataka ultrazvučne terapije proističe iz činjenice da zahteva više poseta.

Low-intensity pulsed ultrasound (LIPUS)

LIPUS is an emerging advancement in the field of ultrasound based therapeutics. It has the potential to be used in management of various nerve, skeletal and muscular diseases. LIPUS refers to pulsed US with an intensity less than 100 mW/cm^2 to target the affected area[32]. LIPUS facilitates transmission of a comparatively lesser amount of energy to the target tissue, thereby preventing thermal damage caused by excessive heat generation at the treatment site[33]. In the recent years including LIPUS including has been explored as a treatment modality for osteoarthritis (OA)of TMJ because of its potential for tissue regeneration[34]. Mechanical overloading of the mandibular condylar cartilage induces the expression of IL-1b, an inflammatory cytokine related closely to the progression of TMJ-OA[35]. In vitro studies by Uddin et al[36] demonstrated that LIPUS can prevent cartilage destruction by inhibiting the catabolic action of IL-1b and they are also known to stimulate migration, proliferation, and differentiation of chondrocytes. Liang et al[37] demonstrated LIPUS in rats and proved that LIPUS can effectively inhibit Chronic sleep deprivation induced injury to condylar cartilage. Thus, LIPUS can serve as an effective non-invasive treatment modality in the management of TMJ OA.

Advantages and Disadvantages of US

The practice of ultrasound therapy for temporomandibular joint disorders has various advantages including cost efficiency, ease of the technique, non-invasive nature of the procedure and active ability to provide significant pain relief[3,4,11]. Ultrasound phonophoresis has an added advantage of minimizing the risk of hepatic and renal injury bu drug elimination as it eliminates the need for systemic drugs and it is also well tolerated by the patients[30]. Rashid et al. conducted a national survey among oral and maxillofacial surgery consultants of United Kingdom (UK) in which 52% of consultants reported ultrasound as an effective electro-physical modality in TMD management[38]. One of the major disadvantages of ultrasound therapy is that it requires multiple visits.

Bezbednosna razmatranja

Terapeutski ultrazvuk kao modalitet fizikalne terapije za poremećaje TMZ-a obično ima nizak rizik od povrede pacijenta onda kada ga koristi kvalifikovano osoblje. Ne preporučuje se ultrazvučna terapija aplikovana na mesto infektivne regije[15]. Postoji dovoljno dokaza u literaturi da su metalni implantati za ultrazvučnu terapiju bezbedni i da ne izazivaju pojačano zagrevanje[39]. Upotreba neodgovarajuće visoke frekvencije i intenziteta može izazvati prekomerno zagrevanje ciljnog tkiva, kao i susednih zdravih tkiva. Upotreba fonoforeze za isporuku lekova kroz kožu može uticati na poroznost kože i izazvati neke histološke promene na koži nakon izlaganja ultrazvuku, ali se koža vraća u normalu kada izlaganje ultrazvuku prestane[3]. Određeni lokalni lekovi koji se koriste za fonoforezu mogu izazvati alergijske reakcije na koži, pa se uvek preporučuje patch test pre početka terapije[30]. Efikasna dezinfekcija sonde neophodna je za sprečavanje bolničkih infekcija. Transduktore treba očistiti nakon upotrebe kvaternarnim amonijumom (sredstvo za dezinfekciju niskog nivoa), sprejevima ili maramicama. Transduktori moraju biti isključeni sa ultrazvučnog skenera.

Održavanje i kontrola infekcija

Oprema za ultrazvučnu terapiju je tehnički složena i zahteva redovnu proveru kvaliteta radi bezbednog rada i provere odgovarajućih ultrazvučnih polja[15]. Upotreba sterilnih sredstava za spajanje i efikasna dezinfekcija sonde od suštinskog su značaja za sprečavanje bolničkih infekcija. Prema Centru za kontrolu i prevenciju bolesti (CKB), terapijski ultrazvuk, koji se koristi za fizikalne terapije, jeste uređaj koji ne dolazi u direktan kontakt sa mukoznim površinama ili neoštećenom kožom. Ovi uređaji zahtevaju nizak nivo dezinfekcije. Sonde se moraju odvojiti od opreme i treba ih očistiti dezinfekcionim sredstvom niskog nivoa nakon svake upotrebe. Prema CKB-u, za efikasnu kontrolu infekcije preporučuje se dezinfekcija niskog nivoa korišćenjem agenasa kao što su 70% do 90% etil alkohola, fenolni germicidni deterdženti, 5,25% do 6,15% natrijum-hipohlorit ili kvaternarni amonijum germicidni rastvor, za vreme izlaganja duže od jednog minuta[40,41].

Safety considerations

Therapeutic ultrasound as a modality of physical therapy for TMJ disorders usually possess a low risk of harm to the patient, when operated by a skilled operator. Ultrasound therapy over an infectious site and open wound is not recommended[15]. There are sufficient literature evidences that claim that ultrasound therapy metal implants are safe and they do not cause increased heating[39]. Use of inappropriate high frequency and intensity may cause excessive heating of the target tissue as well the adjacent normal tissues. Use of phonophoresis for delivery of drugs through the skin can affect the porosity of the skin and can produce some histological changes in skin following ultrasound exposure, but the skin reverts to normal once exposure to ultrasound has stopped[3]. Certain topical drugs used for phonophoresis can cause allergic skin reactions, hence a patch test is always recommended before the start of the therapy[30]. Effective disinfection of the transducer is essential to prevent nosocomial infections. Transducers should be cleaned after use with quaternary ammonium (a low-level disinfectant) sprays or wipes. The transducers must be disconnected from the ultrasound scanner for anything more than wiping or spray cleaning.

Maintenance and Infection control

The ultrasound therapy equipment is technically complex and require quality check on a regular basis for safe operation and verification of appropriate ultrasound fields[15]. Use of sterile coupling agents and effective disinfection of the transducer is essential to prevent nosocomial infections.

According to the Center for Disease Control and Prevention (CDC), therapeutic ultrasound used inphysical therapy is anoncritical device that does not directly contact the mucosal surfaces or non-intact skin. These devices require low-level disinfection. The transducers must be disconnected from the equipment and should be cleaned with a low-level disinfectant after each use. According to CDC, low-level disinfection using agents such as 70–90% ethyl alcohol, phenolic germicidal detergents, 5.25–6.15% of sodium hypochlorite or quaternary ammonium germicidal solution for an exposure time greater than one minute is recommended for effective infection control[40,41].

Zaključak

Terapijski ultrazvuk je dobro poznat elektrofizički modalitet u lečenju poremećaja temporomandibularnog zgloba. Iako je ovaj modalitet široko prihvaćen među kliničarima, fizioterapeutima i pacijentima, nedostaju standardizacija, ultrazvučna dozimetrija i trajanje lečenja. Uz aktivno istraživanje i razvoj, u bliskoj budućnosti mogu se razviti različiti novi terapijski modaliteti zasnovani na ultrazvuku.

Zahvalnica: Nema

Sukob interesa: Nema

Conclusion

Therapeutic ultrasound is a well-known electrophysical modality in the management of temporomandibular joint disorders. Though the modality is a widely accepted among the clinicians, physical therapists and patients, there is a lack of standardization, ultrasound dosimetry, and treatmentduration. With active research and development various new ultrasound based therapeutic modalities can evolve in the near future.

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LITERATURA /REFERENCES

1. Okeson JP. Management of temporomandibular disorders and occlusion. 7th edition. St. Louis, USA: Mosby-Year Book; 2013: 21–3.
2. McNeely ML, Armijo Olivo S, Magee DJ. A systematic review of the effectiveness of physical therapy interventions for temporomandibular disorders. Phys Ther 2006;86(5):710-25.
3. Mason TJ. Therapeutic ultrasound an overview. Ultrason Sonochem 2011;18(4):847-52.
4. Koneru J, Alaparthi R, Yalamanchali S, Reddy RS. Therapeutic ultrasound - The healing sound and its applications in oral diseases: The review of literature. J Orofac Sci 2012; 4:3-6.
5. Miller DL, Smith NB, Bailey MR, Czarnota GJ, Hynynen K, Makin IR; Bioeffects Committee of the American Institute of Ultrasound in Medicine. Overview of therapeutic ultrasound applications and safety considerations. J Ultrasound Med 2012;31(4):623-34.
6. Baker KG, Robertson VJ, Duck FA. A review of therapeutic ultrasound: Biophysical effects. Phys Ther 2001; 81:1351-8.
7. O'Brien WD Jr. Ultrasound-biophysics mechanisms. Prog Biophys Mol Biol 2007;93(1-3):212-55.
8. Kim YS, Rhim H, Choi MJ, Lim HK, Choi D. High-intensity focused ultrasound therapy: an overview for radiologists. Korean J Radiol 2008;9(4):291-302.
9. Watson T. Ultrasound in contemporary physiotherapy practice. Ultrasonics 2008;48(4):321-9.
10. Johns LD. Nonthermal effects of therapeutic ultrasound: the frequency resonance hypothesis. J Athl Train 2002;37(3):293-9.
11. El Ghamrawy A, de Comtes F, Koruk H, Mohammed A, Jones JR, Choi JJ. Acoustic Streaming in a Soft Tissue Microenvironment. Ultrasound Med Biol 2019;45(1):208-217.
12. Brancalion Catapani L, da Costa Gonçalves A, Morano Candeloro N, Rossi LA, Caldeira de Oliveira Guirro E. Influence of therapeutic ultrasound on the biomechanical characteristics of the skin. J Ther Ultrasound 2016;4:21.
13. Stasinopoulos D, Cheimonidou AZ, Chatzidamianos T (2013) Are there Effective Ultrasound Parameters in the Management of Lateral Elbow Tendinopathy? A Systematic Review of the Literature. Int J Phys Med Rehabil 1: 117.
14. Morishita K, Karasuno H, Yokoi Y, Morozumi K, Ogihara H, Ito T, Hanaoka M, Fujiwara T, Fujimoto T, Abe K. Effects of therapeutic ultrasound on range of motion and stretch pain. J Phys Ther Sci 2014; 26(5):711-5.
15. Miller DL, Smith NB, Bailey MR, Czarnota GJ, Hynynen K, Makin IR; Bioeffects Committee of the American Institute of Ultrasound in Medicine. Overview of therapeutic ultrasound applications and safety considerations. J Ultrasound Med 2012;31(4):623-34.
16. Casarotto RA, Adamowski JC, Fallopa F, Bacanelli F. Coupling agents in therapeutic ultrasound: acoustic and thermal behavior. Arch Phys Med Rehabil 2004 ;85(1):162-5.
17. Draper DO, Castel JC, Castel D. Rate of temperature increase in human muscle during 1 MHz and 3 MHz continuous ultrasound. J Orthop Sports Phys Ther 1995; 22:142–150.
18. Stewart H. Ultrasound therapy. In: Respacholi MH, Benwell DA, editors. Essentials of Medical Ultrasound. Clifton, NJ: Humana Press; 1982. p. 196.
19. Hayes BT, Merrick MA, Sandrey MA, Cordova ML. Three-MHz Ultrasound Heats Deeper Into the Tissues Than Originally Theorized. J Athl Train 2004 ;39(3):230-234.
20. Ilter L, Dilek B, Batmaz I, Ulu MA, Sariyildiz MA, Nas K, Cevik R. Efficacy of Pulsed and Continuous Therapeutic Ultrasound in Myofascial Pain Syndrome: A Randomized Controlled Study. Am J Phys Med Rehabil 2015;94(7):547-54.
21. Gray RJ, Quayle AA, Hall CA, Schofield MA. Physiotherapy in the treatment of temporomandibular joint disorders: a comparative study of four treatment methods. Br Dent J 1994;176:257–61.
22. Rai S, Ranjan V, Misra D, Panjwani S. Management of myofascial pain by therapeutic ultrasound and transcutaneous electrical nerve stimulation: A comparative study. European journal of dentistry. 2016;10(1):46.
23. Kirupa K, Divya Mary S, Vaishnavi G, Nisha RN, Mercy JR, Jaiganesh G. A comparative study of ultrasound therapy and transcutaneous electrical nerve stimulation in reducing pain for temporomandibular joint disorder. Drug Invent Today 2019;12(3):515-7.
24. Elgohary HM, Eladl HM, Soliman AH, Soliman ES. Effects of Ultrasound, Laser and Exercises on Temporomandibular Joint Pain and Trismus Following Head and Neck Cancer. Ann Rehabil Med 2018;42(6):846-853.
25. Handa R, Sunil MK, Gupta C, Raina A, Khan T, Gulzar A. Efficacy of ultrasound massage therapy as an adjuvant pain control modality in TMDs:A clinical study. J Indian Acad Oral Med Radiol 2018;30:107-9
26. Saliba S, Mistry DJ, Perrin DH, Gieck J, Weltman A. Phonophoresis and the absorption of dexamethasone in the presence of an occlusive dressing. J Athl Train 2007;42(3):349-54.
27. Ay S, Doğan SK, Evcik D, Başer OC. Comparison the efficacy of phonophoresis and ultrasound therapy in myofascial pain syndrome. Rheumatol Int 2011;31(9):1203-8.
28. Vijayalakshmi KR, Khan M, Rajguru P. Phonophoresis in temporomandibular joint disorders: A clinical trial. J Adv Clin Res Insights 2015;2(6):259-64.
29. Fernandez-Cuadros ME, Casique Bocanegra LO, Albaladejo-Florin M J, Alava-Rabasa S, Perez-Moro O S . Effect of Diclofenac Gel Phonophoresis on Temporomandibular Joint Disorders: A Prospective Quasi-Experimental Study, Middle East J Rehabil Health Stud. Online ahead of Print; 7(3):e102928.
30. Ramakrishnan SN, Aswath N. Comparative efficacy of analgesic gel phonophoresis and ultrasound in the treatment of temporomandibular joint disorders. Indian J Dent Res 2019;30:512-5.
31. Sequeira J, Girishan T. The effect of therapuetic ultrasound and phonophoresis on tmj pain. Int J Sci Res 2020; 35-37.
32. Rutten S, van den Bekerom MP, Sierevelt IN, Nolte PA. Enhancement of Bone-Healing by Low-Intensity Pulsed Ultrasound: A Systematic Review. JBJS Rev 2016 29;4(3):01874474-201603000-00006.

33. Jia L, Wang Y, Chen J, Chen W. Efficacy of focused low-intensity pulsed ultrasound therapy for the management of knee osteoarthritis: a randomized, double blind, placebo-controlled trial. Sci Rep 2016 17;6:35453.
34. Tanaka E, Liu Y, Xia L, Ogasawara N, Sakamaki T, Kano F, Hashimoto N, Feng X, Yamamoto A. Effectiveness of low-intensity pulsed ultrasound on osteoarthritis of the temporomandibular joint: A review. Ann Biomed Eng 2020;48(8):2158-2170.
35. Yoshida H, Fujita S, Nishida M, Iizuka T. Immunohistochemical distribution of lymph capillaries and blood capillaries in the synovial membrane in cases of internal derangement of the temporomandibular joint. J Oral Pathol Med 1997; 26:356–361.
36. Uddin SM, Richbourgh B, Ding Y, Hettinghouse A, Komatsu DE, Qin YX, Liu CJ. Chondro-protective effects of low intensity pulsed ultrasound. Osteoarthritis Cart 2016; 24:1989–1998.
37. Liang C, Yang T, Wu G, Li J, Geng W. Therapeutic effect of low-intensity pulsed ultrasound on temporomandibular joint injury induced by chronic sleep deprivation in rats. Am J Transl Res 2019;11(6):3328-3340.
38. Rashid A, Matthews NS, Cowgill H. Physiotherapy in the management of disorders of the temporomandibular joint—perceived effectiveness and access to services: a national United Kingdom survey. Br J Oral Maxillofac Surg 2013;51(1):52-7.
39. Kocaoğlu B, Cabukoglu C, Ozeras N, Seyhan M, Karahan M, Yalcin S. The effect of therapeutic ultrasound on metallic implants: a study in rats. Arch Phys Med Rehabil. 2011;92(11):1858-62.
40. Frazee BW, Fahimi J, Lambert L, Nagdev A. Emergency department ultrasonographic probe contamination and experimental model of probe disinfection. Ann Emerg Med 2011;58(1):56–63.
41. Hoyer R, Adhikari S, Amini R. Ultrasound transducer disinfection in emergency medicine practice. Antimicrobial Resistance & Infection Control 2016;5(1):1-4.