Review article:

Effects of Extracorporeal Shock Wave Therapy in The Maxillofacial Surgery Practice – A Systematic Review

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Abstract

This review intends to provide researchers with a brief summary of extracorporeal Shock Wave Therapy (ESWT), and to bring new perspectives by systematic reviewing of the available data on the results of the various effects of ESWT regarding dentistry and the maxillofacial area. Literature search was conducted on December 2017 using the PubmedMedline, Google Scholar, Scopus and Web of Science databases.Articles between 1989 and 2018 were included.Search was performed using the keywords 'alveolar, dentoalveolar, maxilla, mandibular, oral and sialolthiasis' words in combination with 'shock wave or shockwave'. The studies that were decided to include to this systematic review (n: 35) mostly consist of experimental and clinical studies. The current systematic review stated that ESWT has a success rate of up to 50% in the treatment of sialolithiasis. Shock wave therapy has also different dose-dependent effects on each tissue in the intraoral region. Shock wave parameters that will bring optimal biological effect to any treatment indication are yet to be clarified.

Keywords : distraction osteogenesis, maxillofacial, shock wave, sialolithiasis, tooth movement

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Introduction

Over the past three decades, shock waves have been used in the noninvasive treatment of renal stones and gallstones[1]. Subsequently, as a result of the developments in shock wave devices, ESWT began to be used in a great number of musculoskeletal system diseases such as osteonecrosis, epicondylitis, nonunion, plantar fasciitis, and tendinitis. The idea of treating different deformities or diseases in the maxillofacial region with ESWT has recently become popular. ESWT was first used in the maxillofacial area after the 1990s, in the treatment of sialolithiasis[2, 3]. Later on, studies on mandibular distraction osteogenesis, fracture and defect healing, acceleration of orthodontic tooth movement and alveolar bone regeneration surged[4-6]. Experimental and clinical studies have confirmed that shock waves have different dose dependent biological and mechanical effects on each tissue[7]. This is because different cells respond differently to shock wave transduction[8]. The mechanism of shock wave effects in the maxillofacial region have not been fully unveiled and the parameters required for optimal treatment outcomes have not been determined. Thus, a critical systematic review would be quite beneficial for clinicians. In this article, we conducted a systematic review to assess the effectiveness and efficiency of ESWT on the treatment of maxillofacial diseases and deformities.

Information Sources and Search

A systematic search of the literature on the effect of the ESWT in the maxillofacial area between 1989 and 2018 was carried out on electronic database (PubMed, Google Scholar, Scopus and Web of Science Database) on December 2017. The articles included were in the English language and focused on the biological and mechanical effects of ESWT in the maxillofacial area. Search was performed using combination of the keywords; 'alveolar',

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'maxilla', 'mandibular', 'oral', 'sialolthiasis', 'shock wave therapy', 'shockwave therapy'. The keywords were searched in the title and abstracts of the studies. The study was formed in two separate sections. The first section includes the clinical trials and case series in which the use of ESWT is reported in the treatment of salivary gland stones; and the second section includes the randomized controlled clinical trials, experimental and in-vitro studies examining the effects of ESWT on orthodontic tooth movement, fracture and defect healing, distraction osteogenesis, alveolar bone regeneration and periodontal status. The reason for this distinction is that ESWT has been in clinical use for a long time in the treatment of sialolithiasis and its success has been proven, while in other areas the studies are largely in the experimental stage.

Inclusion and Exclusion Criteria

Book chapters were not included. Abstract of meetings, single case reports and investigations of the same authors with repeated results were also excluded from this review. In addition, studies in which both ESWT was used in combination with other non-invasive methods were excluded.

As a result of entering the keywords into the electronic database, the studies obtained were independently analyzed by two researchers; and selected according to the inclusion criteria by examining the titles and abstracts of the studies. Studies in which two researchers did not have a consensus were consulted to the third researcher. Subsequently, the full texts of the studies considered to be included in the review were examined.

A total of 483 articles were examined as a result of the literature search. The duplication was avoided through being transferring the citations to the Endnote program. 395 articles were left after eliminating the duplications. In view of inclusion and exclusion criteria, a total of 35 subjects were included in this study and summarized in Table 1 and Table 2.

The contents of the articles in first section of the review were extracted. The publication year, study design, demographic information, ESWT features, average stone size, location of stones, duration of follow-up and success rates were noted from these studies. In the second section, the publication year, study design, ESWT application area, ESWT parameters and study results were extracted and noted. Because of the heterogeneity of the results obtained, it was not available to conduct a meta-analysis of the results.

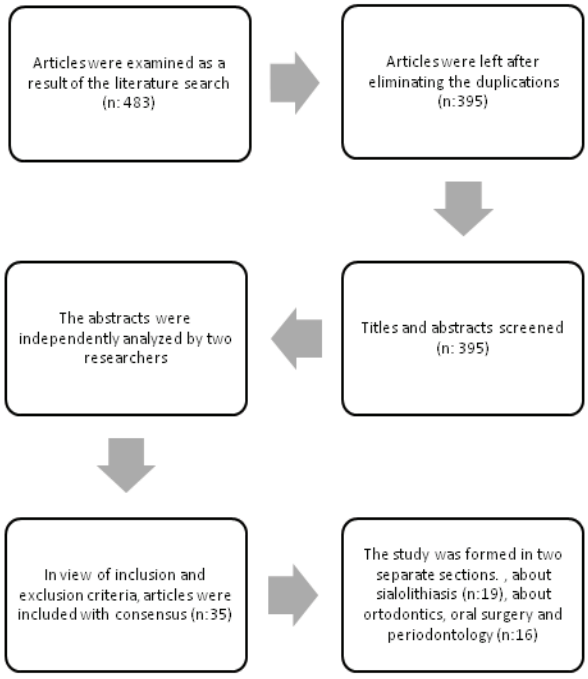

Figure 1 : Flowchart of study

Shock Wave Application Modes

Shock wave is a low frequency high level sonic pulse characterized by high peak pressure (1000 bar-100 MPa) followed by low pressure (100 bar-10 MPa), short life cycle (3-5 μs), fast rising time (10^{-9} s). Shock waves are generated artificially through electrohydraulic, electromagnetic, and piezoelectric methods[1].

Shock wave devices in clinics can be used in different modes (such as focused or unfocused) depending on the nature of the region being treated. Focused shock waves can be generated by all three shock wave generation methods. They can be produced in various focal volume, penetration depth and energy flow density. The characteristic of these shock waves is that the energy can be focused and intensified on a specific part of the tissue (7).

Some electromagnetic and electrohydraulic devices produce unfocused shock waves. These shock waves can reach wider surfaces but penetrate less depths compared to focused shock waves. Thus, unfocused shock waves are generally used in the treatment of superficial lesions, such as skin disease. Another method used in the clinical application of shock waves is radial shock wave therapy. The shock waves produced by these devices that use pneumatic generators, differ from shock waves in many respects including linear pressure, low energy values, and a relatively lower speed of expansion[7].

Therapeutic Applications of Shock waves

Fracture/Bone Defect Healing

The mandible is the most frequently injured (38%) and fractured bone in the maxillofacial area.Although different treatment protocols have been adopted in the world, mandibular fractures are generally treated with open or closed reduction or a combination of these. Despite improvements in trauma surgery, one of the most common complications of fracture healing is the problem of delayed or non- union. Revision surgery is often considered as the first option for the treatment of these conditions[9].

Shock wave therapy's beneficial effects in healing fractures have been demonstrated in several experimental and clinical studies. Studies have reported that shock waves induce the expression of systemic nitric oxide (NO) and osteogenic growth factors (especially TGF-β1 and BMP family), enable the proliferation of mesenchymal cells and differentiation to other cells, thereby increasing callus formation. In addition, it has been reported that shock waves induce angiogenesis by increasing the VEGF level, thereby improving the healing of fractures in long bones[10]. Contrast to these findings, we have observed in our experimental study that shock waves do not have a positive effect on mandibular defect healing in diabetic and nondiabetics[11]. However, another study examining the effect of ESWT on the healing of subcondylar fractures has reported that similar results were obtained with studies on long bones and that cartilage and immature bone formation was induced after histological evaluation[4]. Further studies using different shock wave parameters are needed to correlate the results of these studies.

Sialolithiasis

The prevalence of sialolithiasis in the general population is about 1.2%[12]. It accounts for about half of major salivary gland diseases. Salivary gland stones are most commonly seen in the submandibular gland (80-90%), in the parotid gland (5-10%) and rarely in the sublingual gland (0-5%)[13].

Today, salivary gland stones larger than 1.5 mm can be diagnosed via ultrasound with 99% reliability[13]. Detected stones are traditionally treated by surgical methods. The treatment of the stones in the distal and middle portions of the duct is performed by simple intraoral surgical procedures while the treatment of stones in the proximal, hilus, or intraparenchymal regions of the duct is done by sialoadenectomy[3]. These invasive surgical procedures have risks of nerve (facial, lingual and hypoglossal) damage, skin scarring, Frey's syndrome, and postoperative infection[14]. For this reason, in the past 25 years, minimally invasive and gland-preserving treatment methods have been developed[15] including intracorporeal and extracorporeal shock wave therapy, sialendoscopy, interventional radiology, and endoscopic video-assisted transoral and transcervical stone retrieval options[13]. These methods can be used alone or in combination to increase the success rate[15].

Extracorporeal shock wave lithotripsy (ESWL) was first successfully applied on humans in 1989 by Iro et al.[16]. The purpose of using ESWL is to fragment the salivary gland stone to an average of 2 mm so it can flow out of the duct[17]. ESWL is considered the treatment of choice for all parotid calculi (especially <10mm) and submandibular perihilar or intraparenchymal stones of less than 7 mm[3, 17, 18]. If the size of the stone is over 7 mm or if it is located in the intraglandular region, it reduces the success rate by one third. ESWL was used in the treatment of parotid and submandibular gland stones with an average size of 6.75 mm, and stone-free success was achieved in about half of the cases. The studies showing the results of the effects of ESWL on sialolithasis are summarized in Table 1.

ESWL has local and systemic contraindications. It should not be applied when there is infection present in the head and neck region, or in the case of multiple stones and sialoadenitis, nor should it be applied on patients with coagulopathy, claustrophobia, cardiac pacemakers, or using anticoagulants[19]. ESWL can be applied to almost all age groups. The average age of patients treated with ESWL for sialolithiasis is 40 (Table 1). It has been reported that shock wave lithotripsy can be safely used on children in the treatment of sialolithiasis with minor side effects and successful results[12, 14].

In salivary gland lithotripsy, two main sources of energy are used extracorporeally: piezoelectric and electromagnetic extracorporeal shockwave lithotripsy. Electromagnetic-based shock wave devices are mostly preferred in the treatment of sialolithiasis (Table 1). Although devices for the treatment of renal calculus were used initially, a miniaturized electromagnetic device customized for sialolithiasis (MINILITH SL 1, Storz Medical, Switzerland) was later discovered in 1994[20].

ESWL can also cause untoward effects in the salivary glands and surrounding tissues. In the

Table 1. *Demographic and clinical data, outcomes of ESWL in the treatment of salivary calculi (PE: piezoelectric, EM: Electromagnetic, P: Parotid, SM: Submandibular, mo: month, w: week, y: year)*

	Author	Year	Age (mean or median)	ESWL	Parameters	İmpulse rate (Mean or median)	Calculi Size (mean or median)	Localization	Followup	Symptom free	Stone free
1	Iro at al. (38)	1992	24-67	PE	1-2.5 Hz 40-150 MPa	2130	6,7-12 mm	8 P, 11SM	4 mo	%100	%100
2	Iro at al. (2)	1992	43	PE	1-2.5 Hz 40-150 MPa	2100	8 mm	16P, 35 SM	12 w	%90	%53
3	Kater at al. (24)	1994	14-78	EM	2 Hz 16-18 kV	1000	4-17 mm	29 P, 75 SM	6 mo	%56,6	%38,4
4	Wehrmann at al. (20)	1994	-	EM (Modulith Minilith)	12-16 kV, 2Hz 9-12 kV, 2Hz	1456 1383	7,9 mm 7,8 mm	16P, 24 SM 13P, 20 SM	3 mo	%55 %82	%40 %67
5	Yoshizaki at al. (39)	1996	41,7	PE	2.5 Hz 40-60 MPa	7500	10,05	1 P, 17 SM	Monthly	%71,4	%17
6	Aidan at al. (40)	1996	36	PE	2 Hz 70 MPa	3000-3500	8,2 mm	3 P, 12 SM	5 mo	% 80	% 33
7	Iro at al. (22)	1998	50	PE	2.5 Hz 80 MPa	Up to 3000	5,9 mm	76 P	48 mo	%26	% 50
8	Escuider at al. (14)	1999	12	EM	2 Hz 13-26 MPa	2571	3,75 mm	2 SM	4,5 mo	%100	%50
9	Ottaviani at al. (12)	2001	11,2	EM	-	1350	4,49 mm	3P, 4 SM	32 mo	% 14	%71
10	Külkens at al. (23)	2001	59	PE	0.06 mJ/ mm^2 (Minilith)	2067-2173	7,67 mm	42 P	63 mo	%71	%67
11	Capaccio at al. (41)	2002	33,5	EM	-	-	6,5 mm	2 P, 2 SM (HIV)	44 mo	%75	%75
12	Escuider at al. (3)	2003	43,8	EM	2 Hz 1-36 Mpa	Up to 15000	8,06 mm	38 P, 84 SM	3 mo	%35	%33
13	Capaccio at al. (21)	2004	46,7	EM	0.5-2 Hz grade 1-5	1779	6,62 mm	88 P, 234 SM	57 mo	%87,5	%45
14	Zenk at al. (18)	2004	39	PE	2.5 Hz 80 MPa	Up to 3000	7,2 mm	191 SM	7-12 y	%50,3	% 29
15	Eggers vechilla (19)	2005	48,8	EM	2 Hz 0,066 mJ/mm^2	2000	5,1 mm	22 P, 16 SM	-	%55,3	%28
16	Schmitz at al. (42)	2008	35,6	EM	2 Hz 10-40 MPa	1221,54	5,94 mm	59 P, 126 SM	35,6 mo	%83,2	%31
17	Iro at al. (43)	2009	44,77	EM , PE	2 Hz 30-80 MPa	3000-5000	5,67	738 P, 1364 SM	6 mo	%76,9	%50,9
18	Zenk at al. (44)	2012	-	EM	-	-	8,2 mm	108 P	140 w	%79	%40
19	Desmotz at al. (45)	2014	43	EM	2-6 Hz	4800	6,2 mm	19 P, 6 SM	31 mo	% 48	% 36

studies, pain[21], petechiae[22], ductal bleeding[17,18], swelling[18], salivary hernia[21], sialoadenitis[18,23] temporary hearing impairment[24] and tinnitus[21] have also been reported as untoward effects (written in frequency order). However, these untoward effects occur only during or immediately after the application period of shock wave therapy[17]. Continuous ultrasonographic monitoring during the procedure reduces the number of untoward effects.

When the studies that fulfill the review criterias were examined, a stone-free success rate of 17-100% was obtained after certain follow-up period (1 month-12 years). This rate varies depending on the number of patients included, the location of the stone, the characteristics of the device used, the shock wave parameters, and the size of the stone. However, it can be said that ESWT has an average success rate of 46% in the treatment of sialolithiasis, and 70% if symptom-free is added as a success criterion. This rate is higher in the treatment of parotid calculi than submandibular calculi treatment[15, 22]. When applied with the use of ultrasound, the success rate increases to 70-80% and to 80% with the use of sialendoscopy. When applied in combination with other non-invasive surgical procedures, it has a success rate higher than 90% even in the treatment of impacted/ multiple salivary gland stones[15].

In the studies, shock wave therapy was applied with a varying dose of pulses and number of sessions. Since electromagnetic devices have lower pressure and focus volume, more sessions were applied during the shock wave therapy. The majority of researchers were reported to apply ESWL up to 3 sessions (Table 1). Although different parameters were used for the number of shock waves per session and the energy flux density, applications up to 3000 pulses per session were considered acceptable. There may be changes in the number of sessions, the energy intensity and frequency of shock waves according to the presence of the stone in follow-up. However, both piezoelectric and electromagnetic devices apply shock wave therapy at an average frequency of 2-2.5 Hz (Table 1).

It is very difficult to compare the effectiveness of ESWT on the salivary gland stones and to provide a statistical result because the number of patients, the type of lithotripsy; the size, location and number of stones, success criterion and follow up period vary. But as a result, it can be said that a shock wave therapy is a conservative and successful therapy method that can be applied without anesthesia in salivary gland calculi treatment[2].

Distraction Osteogenesis

One of the major limitations of the distraction osteogenesis (DO) technique is the long treatment period, which is associated with the consolidation phase that takes place in 8 to 12 weeks. Postoperative complications caused by the long duration of bony consolidation are significant concerns. The process of bony consolidation should be accelerated to improve the success rate of DO. A number of methods to promote callus formation have been reported. These attempts include; bisphosphonates, thrombocyte-rich plasma, hormones, demineralized bone matrix, calcium sulphate, electrophysiological applications, low-intensity laser, growth factors, shock waves, ultrasound, hyperbaric oxygen, bone grafts, cytokines, stem cells[5,6]. However, there are no sufficient studies on the effects of ESWT on the new bone formation in DO in the maxillofacial area.

Lai et al. examined the effect of 500 impulses shock wave on consolidation time during the distraction osteogenesis in rat mandibles and reported bone regeneration can be increased via neovascularization and cell proliferation and the expression of osteogenic growth factors[5]. Supporting the importance of the optimal dose shock wave view, Onger et al. revealed that repetition of the 1000 impulses accelerated the consolidation, while 500 impulses extended that period[6] (Table 2).

Table 2. *Treatment protocols reported in previous studies of shock wave therapy on maxillofacial disorders.*

	Authors	Year	Application Area	Parameters	ESWT	Outcomes	Type
1	Sathishkumar at al. (33)	2008	Alveolar Bone Regeneration	100-300-1000 impulses, 5 Hz, 0.1 mJ/mm^2	Electrohydraulic, unfocused	Promising effect	Experimental
2	Novak at al. (35)	2008	Oral bacteria	100-200-300-400-500 impulses, 3 Hz, 0.12-0.22-0.30 mJ/mm^2	Electrohydraulic, unfocused	Promising effect	In Vitro
3	Lai at al. (5)	2010	Mandibular Distraction Osteogenesis	500 impulses, 1 Hz, 0.18 or 0.49 mj/mm^2	Electrohydraulic	Promising effect	Experimental
4	Müller at al. (46)	2011	Calculus and biofilm	3 Hz, 0.4 mJ/mm^2,	Electromagnetic	Not effective to remove calculus, Promising effect to remove biofilm	In Vitro
5	Altuntaş at al. (4)	2012	Subcondylar Fracture	500 impulses, 1 Hz, 4 bar, 0.38 mj/mm^2	Radial	Promising effect	Experimental
6	Hazan-Molina at al. (27)	2013	Cytokine concentration	1000 impulses, 5 Hz, 0.1 mj/mm^2	Electrohydraulic, unfocused	Promising effect	Experimental
7	Falkensammer at al. (28)	2014	Orthodontic tooth movement, Periodontal Status	1000 impulses, 5 Hz, 0.19-0.23 mJ/mm^2	Electrohydraulic, focused	Not significantly effect	Clinical Trial
8	Falkensammer at al. (31)	2014	Stability of mini screw	1000 impulses, 5 Hz, 0.19-0.23 mJ/mm^2	Electrohydraulic, focused	Not effective	Clinical trial
9	Falkensammer at al. (32)	2015	Tooth mobility	1000 impulses, 5 Hz, 0.19-0.23 mJ/mm^2	Electrohydraulic, focused	Promising effect	Clinical trial
10	Falkensammer at al. (30)	2015	Pulpal blood flow	1000 impulses, 5 Hz, 0.19-0.23 mJ/mm^2	Electrohydraulic, focused	Not effective	Clinical trial
11	Hazan-Molina at al. (26)	2015	Periodontal cytokine concentration, ELISA examination	1000 impulses, 5 Hz, 0.10 mJ/mm^2	Electrohydraulic, unfocused	Promising effect	Experimental
12	Hazan-Molina at al. (47)	2015	Periodontal cytokine concentration, Immunoassay examination	1000 impulses, 5 Hz, 0.10 mJ/mm^2	Electrohydraulic, unfocused	Promising effect	Experimental
13	Cai at al. (8)	2016	Periodontal cytokine concentration	100-300-500 impulses, 3 Hz, 0.05-0.10-0.19 mJ/mm^2,	Electrohydraulic, unfocused	Dose related effect	In Vitro
14	Pfaff at al. (48)	2016	Growth Factor in Mandible	1000 impulses, 4 Hz, 0.25 mJ/mm^2	Electromagnetic, focused	Promising effect	Clinical trial
15	Onger at al. (6)	2017	Mandibular Distraction Osteogenesis	500 or 1000 impulses, 2 session, 0.19 mj/mm^2	Electrohydraulic, focused	Promising effect	Experimental
16	Ozkan at al. (11)	2018	Mandibular Defect Healing	500 impulses, 5 Hz, 3 session, 0.19 mj/mm^2	Electrohydraulic, unfocused	Not effective in non-diabetics, Promising effect in diabetics	Experimental

Such a difference between these two studies may be due to the time point of application of the ESWT and/or the repeated stimulation of the healing process. In the first study, a single dose of shock wave therapy was applied on the first day of consolidation while in the second study repeatedly on days 1 and 4. Repetition of shock wave treatment during consolidation may have caused the process to be adversely affected. This is why it may be useful to design new studies that will use a single dose and different energy flux densities in order to determine the optimum effects of ESWT and to support the results.

Orthodontics

Considering the events leading to the osteoclast formation in early phases of tooth movement, the inflammatory cytokines, chemokines and growth factors in the process are very important[25]. The studies described the effect of ESWT on cells of different tissue cultures and reported a marked elevation in different cytokines[23].

Remarkably, shock waves cause changes in cytokine concentration (except TNF-a) only in surrounding tissues of tooth[26] where the inflammatory process has begun. The most important cytokines, whose concentrations change as a result of mechanical forces applied to the tooth, are TNF-a, RANKL, and IL-1β. Shock wave applications increase the level of IL-1B on the PDL compression side in areas subject to orthodontic forces, decrease the RANKL level and the number of TRAP + cells, thus osteoclastogenesis is suppressed[26]. However, it was reported to accelerate periodontal remodeling via increasing the release of IL-1β and VEGF, so it may also increase orthodontic tooth movement[26,27]. This result was supported by a clinical study[28]. Although shock waves have been reported to increase regional blood flow and induce neovascularization[29], there are no findings that they improve pulpal blood flow after orthodontic treatment[30].

The most commonly used tool developed in recent years to provide maximum anchorage in orthodontics is mini screw. Risk factors of using a mini screw include failure of the screw, damage to the periradicular area, and stability issues. The reason of mini screw failure has not yet been clarified. In a randomized controlled study of the effect of shock wave therapy on mini-screw stability, it was reported that ESWT did not have a positive effect on mini screw stability during orthodontic loading[31] (Table 2).

After orthodontic treatment, an increase in tooth mobility is expected. However, periodontal and periradicular tissue regeneration occurs slowly after active orthodontic treatment. Therefore, there is a need for retention after orthodontic treatment. If the retention period after orthodontic treatment can be shortened, possible untoward tooth movements can be avoided. Considering shock wave therapy's tissue healing process and anti-inflammatory[26] effect, it was suggested that it might also reduce dental mobilization after orthodontic treatment. Central, lateral and canine mobility were examined after shock wave therapy applied to the anterior mandibular region, and it was reported that more rapid decrease in mobility was observed in the ESWT treated group[32].

The results of these few studies in the literature suggest that ESWT is a promising, successful noninvasive option in orthodontic treatment (Table 2). As a result, overall clinical effect of ESWT on orthodontic tooth movement biology and the rate of the orthodontic process still need to be determined. The absence of any side effect will allow for further shock wave investigation in orthodontics.

Oral Bacteria and Periodontal Therapy

ESWT has also been a research topic in the field of periodontology, and research has been conducted on alveolar bone regeneration[33], biofilm removal[34], and removal of periodontal pathogens[35]. So far, there has been no report of any harmful effect of ESWT on periodontal cell viability. In addition, pro-inflammatory cytokine release is significantly suppressed in the PDL depending on the dose[26]. These pro-inflammatory cytokines (such as IL-6, IL-8, TNF-α, MCP-1) are mediators that are involved in periodontal diseases and are highly expressed. It has been shown that ESWT causes a dose dependent decrease in IL-6, IL-8, TNF-α and MCP-1, and later on an increase in IL-6 and IL-8 expression[8]. Information from an experimental study showing that IL-6 and TNF-α are significantly reduced as a result of shock waves is consistent with these results[26] (Table 2). However, these results are inconsistent with the effect of shock waves on different chemokines[36]. The reason for this may be the use of different parameters and features in shock wave therapy and its application to different cells.

Traditionally, curettes and ultrasonic devices are used in the mechanical removal of biofilm on teeth and dental calculus. The calculus removal efficacy of ultrasonic instruments is almost 100% while the mechanical effect of ESWT remains at about 5% on average[34](Table 2). The mechanical effect and success of shock waves in the treatment of sialolithiasis was not observed in removing dental calculus. In addition, it was reported that there was a significant reduction in the number of bacteria on the tooth surface though it was not completely removed, showing that its bactericidal action was limited[34]. It has been reported that specific types of oral bacteria are affected by shock waves; however, this effect was reported to vary due to the pathogen types and the energy level used. Different energy levels

can prevent the accumulation of gram positive and gram negative bacteria and some pathogens, such as Streptococcus mutans and Porphyromonas gingivalis, which can cause serious infections. In a study conducted on monoculture suspensions of 6 bacteria types, it was shown that 100 impulse and 0.3 mJ/mm^2 energy flow density shock waves had a bactericide effect on Streptococcus mutans and capsule free Porphyromonas gingivalis, and decreased bacteria accumulation significantly[27]. Shock waves that have a bactericidal effect on the bacteria that play a role in the formation of periodontitis have been tested for the protection of periodontal tissues and alveolar bone (Table 2). In this study, following the ESWT application, alveolar bone regeneration was assessed at 0, 3, 6, and 12 weeks. At the end of the third week, and especially as a result of the 300 and 1000 impulse shock wave therapy, a significant increase was found in alveolar bone levels and this effect was reported to continue for 6 weeks[33]. The fact that shock wave application in a clinical trial did not cause a difference in sulcus depth and gingival index but caused a significant decrease in plaque index, is evidence of the bactericidal effect of ESWT on oral bacteria[28]. In a different study of the same researchers, it was stated that ESWT was associated with a significant decrease in probing depth and bleeding in the study group[32] (Table 2). Because of the positive effect on bone regeneration and the antibacterial characteristic of ESWT, it has been proposed that ESWT can be used as a nonsurgical method in peri-implantitis[37].

In conclusion, shock wave treatment seems to have more biological effects than mechanical on the intraoral region. Its antibacterial and anti-inflammatory effects seem to reduce periodontitis and increase bone regeneration.

Conclusions

Considering the advantages of ESWT reported in the literature, its use in the treatment of different diseases and defects in the maxillofacial area has become forward and experimental applications in this area have produced successful results. The fact that ESWT does not have any important side effects, and its regenerative, anti-inflammatory, and antibacterial effects on soft and hard tissues prove that ESWT can be an effective therapy option in the maxillofacial area. However, the required energy flow density, number of impulses, frequency, and pressure values for shock waves to create optimal biological effects are still not clear. Studies conducted up until this point have proved that the effect of shock wave therapy is dose dependent and differs to applied tissue. Although recent data show that applications in maxillofacial area have been successful, the advantages of shock waves should be proven with further studies in order to determine the most suitable parameters and to make its routine use in practical areas more widespread. In addition, developing special shock wave applicators for use in oral and maxillofacial areas could increase the method's practicability and efficiency in this field.

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