Review Article

The Assessment of the Use of Pulsed Electromagnetic Field Therapy on Healing of Bony Defect after Cyst Enucleation

Aliaa M Habib[1]*, Ragia M Mounir[2], Hesham El-Hawary[3]

1. Associate lecturer of Oral and Maxillofacial Surgery, Oral Surgery Department, Faculty of Oral and Dental Medicine, Cairo University.

2. Professor of Oral and Maxillofacial Surgery, Oral Surgery Department, Faculty of Oral and Dental Medicine, Cairo University.

3. Lecturer of Oral and Maxillofacial Surgery, Oral Surgery Department, Faculty of Oral and Dental Medicine, Cairo University.

*__Corresponding Author: Aliaa M Habib.__ Associate lecturer of Oral and Maxillofacial Surgery, Oral Surgery Department, Faculty of Oral and Dental Medicine, Cairo University.

Received Date: March 16, 2021

Publication Date: April 01, 2021

Abstract

This study aimed to clinically and radiographically evaluate the effect of pulsed electromagnetic field (PEMF) therapy on soft tissue and bony healing after enucleation of cysts and implantation of bioactive glass. Twelve adults, of an equal number of males and females patients with more than 2x2x1 cm size intrabony cysts, were included. Their age ranged from 15-45 years. The cyst was surgically enucleated according to the standard techniques and the resulting surgical defect was grafted using Bioactive glass. Postoperatively patients were divided randomly into two groups' six patients each. ***Group I****: subjected to pulsed electromagnetic field (PEMF) during the healing phase (2hours/ day for 15 days postoperatively).*

Group II: *The control group was not subjected to a pulsed electromagnetic field (PEMF) during the healing phase. Clinically, both groups showed no evidence of graft rejection or infection but a significant reduction of post-operative pain and edema in group I compared to group II. Radiodensity measurement throughout the study showed a decrease in bone density after three months in both groups. Then the radiodensity was raised again at the 6th month radiographic assessment.*

Comparing the two groups, the Independent sample t-test didn't show any statistically significant difference in the bone density between the two groups throughout the study. From the results of the present study, it was concluded that the use of the pulsed electromagnetic field (PEMF) in the maxillary cyst has a valuable effect in decreasing postoperative pain and edema but insignificantly affects bone density.

Keywords: *cyst, cyst enucleation, beta tri-calcium phosphate, bioglass, pulsed electromagnetic field, pulsed electromagnetic waves, panoramic radiography, bone density, edema, pain.*

REVIEW OF LITERATURE

Cysts may remain symptomless for many years. They may become noticeable during the routine dental inspection and radiographic investigation. Enlargement of cysts can lead to facial asymmetry, displacement of teeth and alteration in occlusion, loss of associated or adjacent teeth, and displacement of the denture. In the mandible, a pathological fracture can occur where the cystic lesion has caused resorption of most of the bone. Cysts cause pain and associated tenderness when infected. On very rare occasions the presence of infection within an enlarging cyst in close approximation to the main nerve trunk leads to alteration of sensation in the distribution of a nerve. (1) Enucleation is the process by which the cyst lining is removed. The main advantage is the ability to perform pathologic examinations of the entire cyst lining. Another advantage is that this initial excisional biopsy (i.e., enucleation) has also treated the lesion.

The patient does not have to care for a marsupialization cavity; once the mucoperiosteal flap has healed, the patient is no longer bothered by the cystic cavity. (2,8) Following enucleation of a cyst grafting of the surgically created defect is considered using bone and/or bone substitute. This is to restore the normal architecture, function, and esthetics. (2,4,8,9) Autologous bone is the gold standard by which other graft materials are judged. (10, 11) The limitations of biological bone grafts increase interest in alternatives. Alloplastic has been largely used for its unlimited availability and because it does not require additional donor site surgery with its subsequent morbidity &/or mortality. (12,14) Among the group of alloplastic, particulate bioactive glasses (BG) have been studied considerably.

They act by forming a chemical union with the surrounded tissues. It is the result of a series of interfacial reactions that lead to the formation of a Si-rich layer covered by a Ca–P rich layer. It has been suggested that osteoblasts deposit the organic matrix of bone on this Ca–Player and that the bonding results from cross-linking between ionic sites on the collagen and the mucopolysaccharides with those of the Ca–P rich layer. Besides being osteoconductive, BG particles have demonstrated an osteostimulatory effect. (14,21) Pulsed electromagnetic field (PEMF) therapy is a form of alternative medicine which claimed to treat disease by applying electromagnetic energy to the body. (22,23) Based upon multicenter, randomized, and prospective clinical studies, the Food and Drug Administration, USA, approved pulsed electromagnetic field (PEMF) as a safe and effective method for treating fractures nonunions and for osteoporosis therapy. (24, 25) It affects bone metabolism, both in vivo and in vitro.

In vivo, it can improve bone mineral density (BMD) and biomechanical properties and decelerate the bone resorption process. (26, 27) While in vitro it can enhance osteoblast activity with a significant reduction in osteoclast formation, activity, and survival shifting the balance towards osteogenesis by affecting both pathways of bone metabolism. (28,30) It stimulates osteogenesis in patients with fracture non-union. It was also applied as an adjunct treatment of delayed healing of foot and ankle arthrodesis, but with a relatively low success rate. (31,33) In spinal surgery, increased the success of radiological spinal fusion and accelerated the regeneration process. (34, 35) During limb lengthening procedures including the humerus, femur, and tibia, a pulsed electromagnetic field (PEMF) was found to encourage callus formation and maturation at the distraction site, allowing earlier removal of the external fixation devices. (36)

A large number of scientific and clinical studies have been reporting that pulsed electromagnetic fields (PEMF) helped in bone unification; reduce pain, edema, and inflammation; increase blood circulation; stimulate immune and endocrine systems. Most of these wound studies involve arterial or venous skin ulcers, diabetic ulcers, pressure ulcers as well as surgical and burn wounds. Since cells involved in wound repair are electrically charged, some endogenous electromagnetic field signals may facilitate cellular migration to the wound area, thereby restoring normal electrostatic and metabolic conditions. A pulsed electromagnetic field (PEMF) has also been beneficial in the treatment of chronic pain associated with connective tissue (cartilage, tendon, ligaments, and bone) injury and joint-associated soft tissue injury. (37,39)

A meta-analysis performed on randomized clinical trials using pulsed electromagnetic field (PEMF) on soft tissues and joints showed that pulsed electromagnetic field (PEMF) was effective in accelerating healing of skin wounds, soft tissue injury, as well as providing symptomatic relief in patients with osteoarthritis and other joint conditions. **(**40,53**)**

PATIENTS AND METHODS

Patients' selection: 12 patients suffering from intrabony maxillary cysts were selected from the outpatient clinic; Oral Surgery Department, Faculty of Oral and Dental Medicine, Cairo University. They were physically healthy and with no known history of systemic and/or local disease that might affect bone grafting and the healing process. The cyst was more than 2x2x1 cm in dimensions as measured from preoperative radiographs. The definitive diagnosis was reached after performing aspiration and incisional biopsy.

Surgical procedure: Cysts were surgically enucleated according to the standard techniques and the resulting surgical defects were grafted using Bioactive glass **[**1**]**. Compressed sheets of gel foam **[**2**]** were used as a mechanical barrier in cases of sinus or nasal lining exposure also to cover the graft to prevent injury to the covering mucoperiosteum **(Fig 01)**.

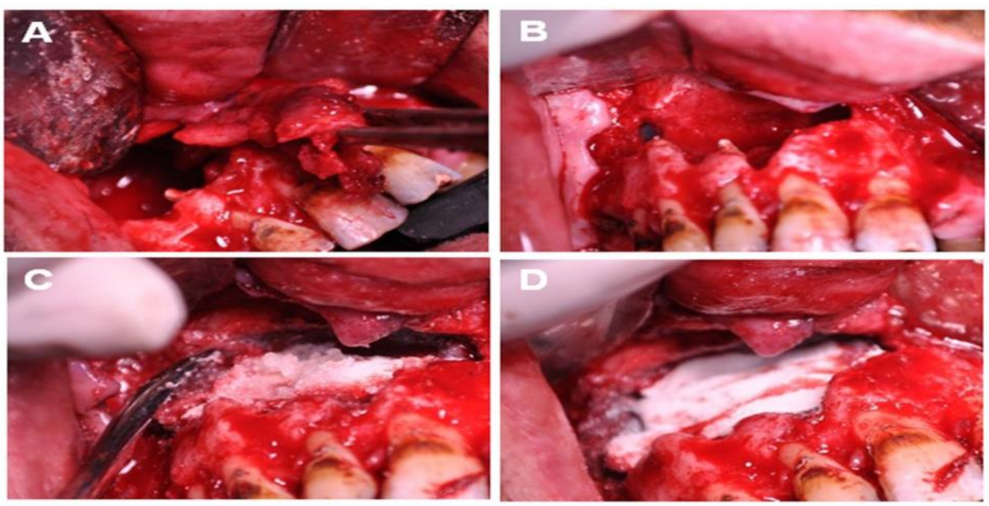

Fig 01: (A) Cyst lining during enucleation.
(B) Surgical defect resulted from cyst enucleation.
(C) Grafting of the surgically created defect with beta tri-calcium phosphate.
(D) Packed layer of Gel Foam covering the grafted site.

Postoperative medications: All the patients were instructed to take these medications: Clindamycin HCl **[**1**]** 300 mg tablets every 8 hours for 5 days post-surgical. Ketoprofen **[**2**]** 50 mg analgesic tablets were given whenever needed three times daily for 3-5 days postoperatively. Mouth rinsing with 0.12% Chlorhexidine gluconate **[**3**]** 3 times per day starts the day after surgery. In cases with sinus or nasal mucosa approximation; Decongestant nasal drops **[**4**]** were prescribed three times daily for 10 days. Antihistaminic **[**5**]** Fexofenadine 120 mg once daily.

Patients grouping: Postoperatively patients were divided randomly into two equal groups. Group, I (The study group) was subjected to pulsed electromagnetic field **[**6**]** (PEMF) during the healing phase starting 24 hours postoperatively, 2hours/day, for 15 days. Group II (The control group) was not subjected to pulsed electromagnetic field (PEMF) during the healing phase **(Fig 02).**

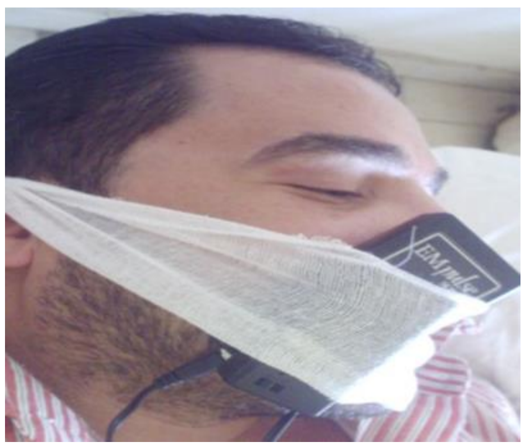

Fig 02: Clinical Photograph showing the pulsed electromagnetic waves device in position.

Clinical evaluation

Patients were evaluated for the degree of postoperative pain and edema. Pain is measured utilizing the visual analog score (VAS) as described by Myles **(**54**)** et al., to measure the patient's current level of postoperative pain. A 100 mm VAS enumerated from 0 to 10; that had ends marked with "no pain" at the zero points and "worst pain ever" at the 10 points. Patients were asked to consider different amounts of pain every day for seven days. It was accepted that patients would be influenced by their first VAS recording. So each successive rating was concealed after completion.

The evaluation of the edema (facial swelling) was performed using a horizontal and vertical guide with a flexible ruler following control points as described by Amin **(**55**)** et al., in 1983 and Neupert **(**56**)** et al., in 1992. The reference points used for measuring edema were: The angle of the mandible to the external canthus of the eye on each side (Fig.3A). The angle of the mandible to the ala of the nose on each side **(Fig.3B).** The tip of the tragus to the lip commissure on each side **(Fig. 3C).** The mean of these lines was calculated and recorded in centimeters. The measurements were taken 24 hours postoperatively and one week later.

Fig 03: Clinical photograph showing

(A) Measurement of facial edema from the angle of the mandible to the external canthus of the eye.

(B) Measurement of facial edema from the angle of the mandible to the ala of the nose.

(C) Measurement of facial edema from the tip of tragus to the lip commisure.

Radiographic Evaluation

The radiographic evaluation was performed for each patient by obtaining a digital panorama. All digital radiographs were taken with the same machine **[**1**]** and the same parameters to provide standardization of images. Standardization of the patient position was performed in all 3 dimensions through adjusting the light beam of the frankfurt horizontal plane for vertical orientation, canine line beam for anteroposterior positioning, and the midsagittal light beam for horizontal orientation. The image plate was exposed with the panoramic machine and the digital image was obtained on the workstation through the laser scanner and manipulated using the software **[**2**]** was performed. All radiographs were performed at the following intervals: immediate, 3, and 6 months postoperatively. The technical magnification of the panoramic view was considered to be 1:3.

Radiographic Image Analysis

Panoramic images were analyzed by one radiologist. Each image was analyzed twice by the same examiner at two different sessions with two weeks intervals in between. Radiodensitometric analysis was obtained by measurement of the relative bone density using the sigma view, Digora software **(fig. 04).** The recorded measurements were investigated through further statistical analysis and the difference in the mean values showed the changes in the healing of the bony defects. The mean of the two readings was calculated and included in further statistical analysis to eliminate any intra-observer variation.

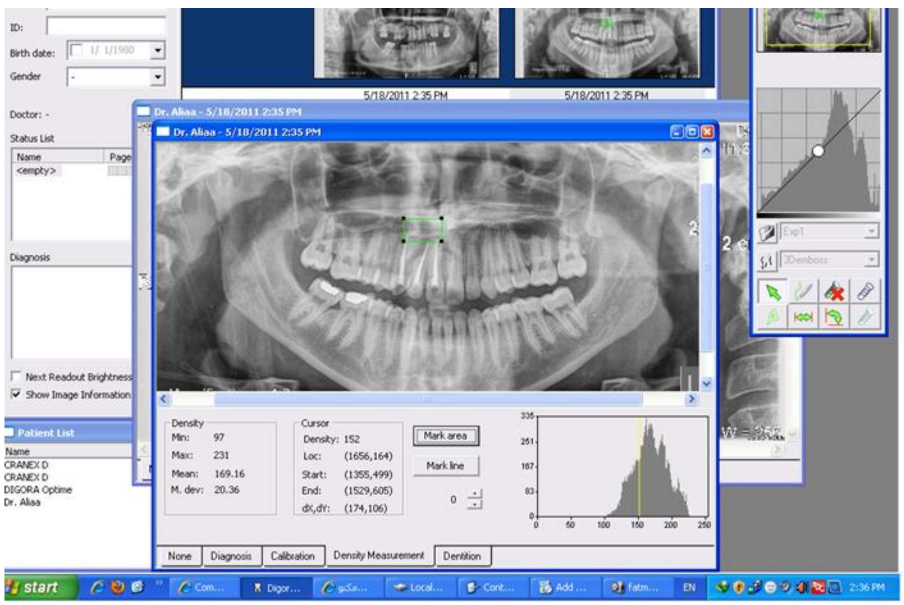

Fig 04: Photograph showing the screen print of the bone density measurement from orthopantomogram of the patient N using Digora software.

RESULTS

Clinical examination for both groups showed no evidence of graft rejection or infection. All patients attained their follow-up recalls. Statistical analysis was performed using SPSS (Statistical Package for the social sciences) version 15, Microsoft Corp., U.S.A. Data were represented as mean + standard deviation. Paired Student t-test was used to compare two variables within the same group. Independent samples t-test was used to compare variables between the two studied groups. The result was considered statistically significant if the p-value was less than 0.05.

Clinical Results

Regarding the postoperative edema; in group I postoperative edema ranged from 0 to 28.8 mm (mean 18.86 mm + 10.93) 24 hours postoperatively. One week later edema subsides to a mean of 20.65 mm + 10.13 mm. There was a statistically significant decrease in edema formation one week postoperative compared to the first postoperative day p=0.044. Similarly in group II, it reduced significantly one week postoperative 20.56 mm + 10.13 when compared to the 1st postoperative day mean value 22.48 + 18.55 p=0.043. Comparing the two studied groups revealed a statistically significant decrease of edema in group I at 24 hours as well as 7 days postoperatively p=0.044, 0.047 respectively **(Table01).**

	24 hours		7 days	
	Mean ±STD	P value	Mean ± STD	P value
Group I	18.86±10.93	0.044	16.01±8.25	0.047
Group II	22.48±18.55		20.56±10.13	

Table 01: Comparing the two studied groups regarding postoperative edema.

Concerning Postoperative pain; it was assessed in the two studied groups on daily basis for the first postoperative week. The results showed no statistically significant difference between the two groups in the first postoperative day p= 0.157. However, starting from the second postoperative day onwards there was a statistically significant reduction of post-operative pain in group I compared to group II with p values ranging from 0.003 to 0.001 **(Table 02).**

Table 02: Postoperative pain between the two studied groups.

	1st day		2nd day		3rd day		4th day		5th day		6th day		7th day	
	Mean±STD	P value	Mean±STD	P value	Mean±STD	P value	Mean±STD	P value	Mean±STD	P value	Mean±STD	P value	Mean±STD	P value
Group I	7.83 ± 1.16	0.157	5.16 ± 1.16	0.003	2.83 ± 0.98	0.002	0.83 ± 0.98	0.001	0.33 ± 0.51	0.001	0.00 ± 0.00	0.001	0.00 ± 0.00	0.001
Group II	8.33 ± 1.03		7.0 ± 1.41		5.83 ± 1.16		3.83 ± 1.16		2.33 ± 1.03		1.66 ± 1.21		1.0 ± 0.89	

Radiodensitometric Results

The radiodensirometric analysis showed that the mean value of the bone density measured immediately postoperatively was 137.92HU + 34.02HU. By the end of the third month it was reduced to 106.55 HU + 38.94HU. At six month postoperatively it reached 122.65HU + 31.93HU. The percentage change of the bone density throughout the study was -22.61% and -7.22 by the end of the third and the sixth months respectively.

There was a statistical significant difference in the mean values of the bone density three months postoperatively p= 0.002 as well as six months postoperatively p= 0.004 **(Table 03).** While in group II the mean value of the bone density measured immediately postoperatively was 131.78 HU + 20.36 HU. Three months postoperative it was reduced to 126.42 HU + 27.024HU. By the end of the sixth month postoperatively it reached 138.05HU + 15.14HU. The percentage change of the bone density at three months was -4.08 % where it was 7.67 % at sixth months postoperatively.

	Min	Max	Mean	Std
Immediate	89.74	184.47	137.92	34.02
3 months	60.64	161.32	106.55	38.94
6 months	76.87	169.16	122.65	31.93
Percentage change at 3m	-53.45	5.78	-22.61	20.47
Percentage change at 6m	-52.79	18.64	-7.22	25.27

Table 03: bone density group I.

There was a statistical significant difference in the mean values of the bone density three months postoperatively p= 0.001 as well as six months postoperatively p= 0.009 **(Table 04).** Independent sample t-test to compare the two groups didn't show any statistical significant difference in the bone density between the two groups throughout the study. p=0.5, 0.1, 0.1 immediate, three and six months postoperative respectively **(Table 05).**

	Min	Max	Mean	Std
Immediate	105.77	151.65	131.78	20.36
3 months	88.66	152.94	126.42	27.02
6 months	111.01	150.78	138.05	14.14
Percentage change at 3m	-19.42	0.85	-4.8	7.7
Percentage change at 6m	-24.13	37.04	7.67	22.9

Table 04: bone density group II

	Immediate		3 month		6 month	
	Mean+ STD	P value	Mean +STD	P value	Mean +STD	P value
Group I	137.92+34.02	0.5	106.55+38.94	0.1	122.65+31.93	0. 1
Group II	131.78+20.36		126.42+27.02		138.05+14.14	

Table 05: Comparing bone density of the two groups.

Discussion

The present study was conducted to evaluate and compare clinically and radiographically the effect of pulsed electromagnetic field on the healing of cystic defect of the jaws. The results of this study prove that the pulsed electromagnetic field decreases the postoperative pain and edema following cyst enucleation and grafting of the surgically created defect.

For all patients, bioactive glass particles mixed with saline and applied after cyst enucleation to fill intrabony defect. Upon implantation of the bioactive glass, the material seemed to be coherent in the defect, easy to be manipulated and has a hemostasis effect. This is by the results stated by Abd-el azym (55) and El Sherbiny in 1999 which proved the coherence of the bioglass inside the bony defect.

In the present study, compressed sheets of gel foam were used as a mechanical barrier in cases of sinus or nasal lining exposure also in one case of nasal floor perforation and another one of sinus lining tear and suturing with no infection or any complications. The compressed gel foam sheet acted as a mechanical barrier that prevented mechanical irritation of the delicate respiratory mucosa and/or escapes of the graft material into the sinus or through the nose as reported by Dong-Seok Sohn (56) in 2010.

As the bioactive glass granules are rough and sharp, A compressed sheet of gel foam was used in all cases of the present study to cover the grafted cavity before repositioning the mucoperiosteal flap. That prevented the oral mucosa irritation and escape of the graft material from the flap.

The present study proved that a pulsed electromagnetic field significantly reduces postoperative pain. This was a common result in most of the studies carried upon the effect of pulsed electromagnetic field (PEMF) on pain as in the work of Lee (37) et al., (1993). These results may be attributed to the analgesic and anti-inflammatory effects of pulsed electromagnetic field therapy at the cellular level.

Regarding postoperative edema, the comparison of the two groups revealed a statistically significant decrease of edema in group I (that was subjected to pulsed electromagnetic field (PEMF) sessions) at twenty-four hours as well as seven days postoperatively [P=0.444, 0.047 respectively] that met a great agreement through the literature in the studies of Lee (37) et al., in1993.

The mechanism of action of pulsed electromagnetic field (PEMF) signals on tissue growth and repair are not completely known at this time. Generally, it has been established that inflammation is characterized by massive infiltration of T lymphocytes, neutrophils, and macrophages into the damaged tissue by Gessi(57) et al., (2000) study. The experimental work of Lee (37) et al., in 1993 suggested that pulsed electromagnetic field (PEMF) was able to suppress the extravascular edema during early inflammation. Direct digital radiography (DDR) was used to measure the changes in the density of the grafted cystic bony defects in both groups through the specific follow-up periods: immediately, three then six months post-operatively. Barbet(58) and Messer in 1998 stated that direct digital radiography (DDR) has proven to be a more accurate, sensitive, and reliable alternative technique to routine x-rays. Also, it offers a lower level of irradiation to the patient and decreases the time consumption for both the patient and operator.

Radiodensity measurement throughout the study showed a decrease in bone density after three months in both groups. This decrease in density was due to the formation of a soluble silica layer that is readily absorbed and excreted from the body. In addition to excavation of the granule core by phagocytosis and early osteoid formation within the excavated chambers. That was coincident with the studies of Oonishi (59) et al., in 1997 and Gaisser (60) et al., in 2002. In both groups, the radiodensity raised again at the 6th month radiographic assessment. That increase in radiodensity was thought to be because of new bone formation after the invasion of osteoblasts as a result of the osteostimulatory effect of bioactive glass which is coincident with the studies of Schepers (18) et al., (1991), Schepers(19) et al., (1997), Furusawa(20) et al., (1998), From(21) et al., (2002), and Norton(14), (2002).

Comparing the two groups, the Independent sample t-test didn't show any statistically significant difference in the bone density between the two groups throughout the study. p=0.5, 0.1, 0.1 immediate, three and six months postoperative respectively. That was contrary to many literature studies that showed the positive effect of the PFMF on increasing the bone density in fracture line, fracture nonunion and osteoporosis (Sharrard (31) et al., 1982, Ito(61) and Shirai 2001 and Mustafa(62), 2004). But this insignificant difference in the bone density after application of pulsed electromagnetic field (PEMF) was consistent with the results of the studies of Giordano(63) et al., (2001), Huang(64) et al., Zhou (65) et al., in 2006, Gao(66) et al., in 2006. The common result in their work was an insignificant change in the bone mineral density between the control group and the study one. They concluded that pulsed electromagnetic field (PEMF) doesn't affect the bone mineral density.

Conclusion

The local use of the pulsed electromagnetic field (PEMF) during the first two weeks following maxillary cyst enucleation has a valuable effect in decreasing postoperative pain and edema but insignificantly affects bone density.

References

1.Cowpe JG: Benign Cysts: oral and maxillofacial surgery an objective based textbook, "Churchill livingstone an imprint of Elesiver science limited Publishers, spain"; 108-110, 2001.

2.Chiapasco M, Rossi A, Motta JJ, Crescentini M: Spontaneous bone regeneration after enucleation of large mandibular cysts: "a radiographic computed analysis of 27 consecutive cases". J Oral Maxillofac Surg. Sep;58(9):942, 2000; discussion 949.

3.Ledesma-Montes C, Hernández-Guerrero JC, Garcés-Ortíz M: "Clinico-pathologic study of odontogenic cysts in a Mexican sample population". Arch Med Res.; 31: 373, 2000.

4.Ellis E: Contemporary Oral and Maxillofacial Surgery, 4th Ed, Mosby puplisher; 468, 2002.

5.Mosqueda-Taylor A, Irigoyen-Camacho ME, Diaz-Franco MA, Torres-Tejero MA: "Odontogenic cysts". Analysis of 856 cases. Med Oral; 7: 89, 2002.

6.Nary Filho H, Matsumoto MA, Fraga SC, Gonçales ES, Sérvulo F: "Periapical radiolucency mimicking an odontogenic cyst”. Int Endod J.; 37: 337, 2004.

7.Ochsenius G, Escobar E, Godoy L, Peñafiel C: “Odontogenic cysts: analysis of 2,944 cases in Chile. Med Oral Patol Oral Cir Bucal”. 12:E85, 2007.

8.Riachi F, Tabarani C: “Effective Management of Large Radicular Cysts Using Surgical Enucleation vs. Marsupialization”. . IAJD; 1(1): 44, 2009.

9.Marble HB, Captain DC USN: “Homografts of freeze –dried bone in cystic defects of the jaws”. Federal dental services; 26(1): 118, 1968.

10.Iain HK: Principles of bone healing: “Neurosurg”. Focus; 10 (1), 2001.

11.Boyne P: “Methods of osseous reconstruction of the mandible following surgical resection”. J Biomed Mat.; 4:195, 1973.

12.Freidlaender GE: “Immune responses to osteochondral allografts Current knowledge and future directions”. Clin Orthop.; 174: 58, 1983.

13.Topazian RG, Hammer WB, Boucher LJ, Hulbert SF: “Use of alloplastics for ridge augmentation”. J Oral Surg.; 29: 792, 1971.

14.Norton MR & Wilson J: Dental implants placed in extraction sites implanted with bioactive glass: “human histology and clinical outcome”. International Journal of Oral & Maxillofacial Implants; 17: 249, 2002.

15.Hench LL, Splinter RJ, Allen WC, Greenlee TK: “Bonding mechanisms at the interface of ceramic prosthetic materials”. J Biomed Mat Research Symp.; 2: 117,1971.

16.Hench LL, Paschall HA: “Direct chemical bond of bioactive glass–ceramic materials to bone and muscle”. J Biomed MatResearch; 7: 25, 1973.

17.Hench LL, Paschall HA: “Histochemical responses at a biomaterial’s interface”. J Biomed Mat Research Symp.; 5: 49,1974.

18.Schepers E, De Clercq M, Ducheyne P, Kempeneers R: “Bioactive glass particulate material as filler for bone lesions”. J Oral Rehabilitation; 18: 439, 1991.

19.Schepers EJ, Ducheyne P: Bioactive glass particles of narrow size range for the treatment of oral bone defects: “a 1–24 month experiment with severalmaterials and particle sizes and size ranges”. J Oral Rehabilitation; 24: 171, 1997.

20.Furusawa T, Mizunuma K, Yamashita S, Takahashi T: “Investigation of early bone formation using resorbable bioactive glass in the rat mandible”. Int J Oral Maxillofac Implants; 13: 672, 1998.

21.Froum S, Cho SC, Rosenberg E, Rohrer M, Tarnow D: “Histological comparison of healing extraction sockets implanted with bioactive glass or demineralized freeze-dried bone allograft: a pilot study”. J Periodontol. Jan;73(1):94, 2002.

22.Gordon GA: “Designed electromagnetic pulsed therapy: Clinical applications”. J Cell Physiol.; 212(3):579, 2007.

23.Luben RA: “Effects of low-energy electromagnetic fields (pulsed and DC) on membrane signal transduction processes in biological systems”. Health Phys; 61(1): 15, 1991.

24.Bassett CA: “Fundamental and practical aspects of therapeutic uses of pulsed electromagnetic fields (PEMFs)”. Crit Rev Biomed Eng; 17: 451, 1989.

25.Chao EY, Inoue N, Koo TK, Kim YH: “Biomechanical considerations of fracture treatment and bone quality maintenance in elderly patients and patients with osteoporosis”. Clin Orthop Relat Res; 425: 12, 2004.

26.Jayanand BJ, Lochan R: “Effects of low level pulsed radio frequency fields on induced osteoporosis in rat bone”. Indian J Exp Biol; 41: 581, 2003.

27.Luo E, Jiao L, Shen G, Wu XM, Xu Q, Lu L: “Effects of the PEMFs of different intensity on BMD and biomechanical properties of rabbits’ femur”. J Biomed Eng; 22: 1168, 2005.

28.Yonemori K, Matsunaga S, Ishidou Y.: “Early effects of electrical stimulation on osteogenesis”. Bone; 19: 173, 1996.

29.Bodamyali T, Bhatt B, Hughes FJ, Winrow VR, Kanczler JM, Simon B, Abbott J, Blake DR, Stevens CR: “Pulsed electromagnetic fields simultaneously induce osteogenesis and upregulate transcription of bone morphogenetic proteins 2 and 4 in rat osteoblasts in vitro”. Biochem Biophys Res Commun; 250: 458, 1998.

30.Chang K, Chang WH, Yu YH, Shih C: “Pulsed electromagnetic field stimulation of bone marrow cells derived from ovariectomized rats affects osteoclast formation and local factor production”. Bioelectromagnetics; 25: 134, 2004.

31.Sharrard WJ, Sutcliffe ML, Robson MJ, Maceachern AG: “The treatment of fibrous non-union of fractures by pulsing electromagnetic stimulation”. J Bone Joint Surg Br; 64:189, 1982.

32.Itoh M, Montemayor JSJr., Matsumoto E, Eason A, Lee MH, & Folk FS: “Accelerated wound healing of pressure ulcers by pulsed high peak power electromagnetic energy (Diapulse), Decubitus; 4: 24,1991”.

33.Saltzman C, Lightfoot A, Amendola A: “PEMF as treatment for delayed healing of foot and ankle arthrodesis”. Foot Ankle Int; 25:771, 2004.

34.Bose B: “Outcomes after posterolateral lumbar fusion with instrumentation in patients treated with adjunctive pulsed electromagnetic field stimulation”. Adv Ther; 18:12, 2001.

35.Linovitz RJ, Pathria M, Bernhardt M, Green D, Law MD, McGuire RA, Montesano PX, Rechtine G, Salib RM, Ryaby JT, Faden JS, Ponder R, Muenz LR, Magee FP, Garfin SA: Combined magnetic fields accelerate and increase spine fusion: “a double-blind, randomized, placebo controlled study”. Spine; 27:1383, 2002.

36.Luna Gonzalez F, Lopez Arevalo R, Meschian Coretti S, Urbano Labajos V, Delgado Rufino B:”Pulsed electromagnetic stimulation of regenerate bone in lengthening procedures”. Acta Orthop Belg; 71:571, 2005.

37.Lee RC, Canaday DJ, Doong H: “A review of the biophysical basis for the clinical application of electric fields in soft-tissue repair”. J of Burn Care and Rehabilitation; 14: 319, 1993.

38.Rosch PJ, Markov MS: “Bioelectromagnetic Medicine”. NY: Marcel Dekker: 2004.

39.Hazlewood CF, Markov MS: “Magnetic fields for relief of myofascial and/or low back pain through trigger points”. In P. Kostarakis (Ed.), Proceedings of Forth International Workshop Biological effects of electromagnetic fields; 475:483, 2006

40.Bental RHC: “Low-level pulsed radiofrequency fields and the treatment of soft-tissue injuries”. Bioelectrochem Bioenergetics; 16: 531, 1986.

41.Foley-Nolan D, Barry C, Coughlan RJ, O’Connor P, Roden D: Pulsed high frequency (27 MHz) Electromagnetic therapy for persistent neck pain: “a double blind placebo-controlled study of 20 patients”. Orthopedics; 13: 445, 1990.

42.Ieran M, Zaffuto S, Bagnacani M, Annovi M, Moratti A, Cadossi R: “Effect of low frequency electromagnetic fields on skin ulcers of venous origin in humans: a double blind study”. J of Orthopedic. Res; 8: 276, 1990.

43.Itoh M, Montemayor JSJr., Matsumoto E, Eason A, Lee MH, & Folk FS: “Accelerated wound healing of pressure ulcers by pulsed high peak power electromagnetic energy (Diapulse), Decubitus; 4: 24,1991”.

44.Stiller MJ, Pak GH, Pack JL, Thaler S, Kenny C, & Jondreau L: “A portable pulsed electromagnetic field (PEMF) device to enhance healing of recalcitrant venous ulcers: A double-blind, placebo- controlled clinical trial”. The British J of Dermatology; 127: 147, 1992.

45.Vodovnik L, Karba R: “Treatment of chronic wounds by means of electric and electromagnetic fields”. Medical & Biological Engineering & Computing; 30: 257, 1992.

46.Comorosan S, Vasilco R, Arghiropol M, Paslaru L, Jieanu V, Stelea S: “The effect of Diapulse therapy on the healing of decubitus ulcer. Romanian J of Physiology ; 30: 41,1993”.

47.Pennington GM, Danley DL, Sumko MH: “Pulsed, non-thermal, high frequency electromagnetic energy (Diapulse) in the treatment of grade I and grade II ankle sprains”. Military Medicine; 158: 101, 1993.

48.Fitzsimmons RJ, Ryaby JT, Magee FP, Baylink DJ: “Combined magnetic fields increase net calcium flux in bone cells”. Calcified Tissue International; 55: 376, 1994.

49.Zizic T, Hoffman P, Holt D., Hungerford J, O'Dell J, Jacobs M: "The treatment of osteoarthritis of the knee with pulsed electrical stimulation". J Rheumatology; 22:1757, 1995.

50.Pilla AA, Martin DE, Schuett AM: "Effect of pulsed radiofrequency therapy on edema from grades I and II ankle sprains: A placebo controlled, randomized, multi-site, double blind clinical study". J Athletic Training; S31: 53, 1996.

51.Seaborne D, Quirion-DeGirardi C, Rousseau M: "The treatment of pressure sores using pulsed electromagnetic energy (PEME)". Physiotherapy Canada; 48: 131, 1996.

52.Ryaby JT: "Clinical effects of electromagnetic and electric fields on fracture healing". Clin Orthop; 355(suppl): 205, 1998.

53.Canedo-Dorantes L, Garcia-Cantu R, Barrera R, Mendez-Ramirez I, Navarro VH, Serrano G: "Healing of chronic arterial and venous leg ulcers with systemic electromagnetic fields". Archives of Medical Research; 33: 281,2002.

54.Myles P, Troedel S, Boquest M, Reeves M: "The Pain Visual Analog Scale: Is It Linear or Nonlinear". Anesth Analg; 89:1517, 1999.

55.Abdel-Azym A and El-Sherbiny M: "Direct digital radiography and SPECT for evaluation of bioactive glass coated dental implants". Egyptian Dental J; 45: 4189, 1999.

56.Dong-Seok Sohn, Jee-Won Moon, Kyung-Nam Moon, Sang-Choon Cho , Pil-Seoung Kang: "New Bone Formation in the Maxillary Sinus Using Only Absorbable Gelatin Sponge". J Oral Maxillofac Surg; 68:1327, 2010.

57.GESSI S, VARANI K, MERIGHI S, ONGINI E, BOREA PA: "A2A adenosine receptors in human peripheral blood cells". Br. J Pharmacol.; 129: 2, 2000.

58.Bardbet J, Messer HH: "Detectability of artificial periapical lesions using direct digital and conventional radiography". J. Endod.; 24(12):837, (1998).

59.Oonishi H, Kushitani S, Yasukawa E, Iwaki H, Hench LL, Wilson J, Tsuji E, Sugihara T: "Particulate bioglass compared with hydroxyapatite as a bone graft substitute". Clin Orthop Relat Res.; 334:316, 1997.

60.Gaisser DM, Wheeler DL, Greenspan DC: "In vivo absorbability of 45S5 Bioglass® bioactive glass - A histologic analysis, Trans". 28th Annual Meeting Society for Biomaterials; 25:400, 2002.

61.Ito H, Shirai Y: "The efficacy of ununited tibial fracture treatment using pulsing electromagnetic fields: relation to biological activity on nonunion bone ends". J Nihon Med Sch; 68(2):149, 2001.

62.Mustafa AF:" Effect of Pulsed Electromagnetic Field on Healing of Mandibular Fracture". A thesis submitted for partial fulfillment of requirements of the master degree in Oral and Maxillofacial surgery. Faculty of Oral & Dental Medicine. Cairo University, 2009.

63.Giordano N, Battisti E, Geraci S, Fortunato M, Santacroce C, Rigato M: "Effect of electromagnetic fields on bone mineral density and biochemical markers of bone turnover in osteoporosis: a single-blind, randomized pilot study". Curr Ther Res Clin E; 62: 187, 2001.

64.Huang S, Meng P, Cai HW: "Effect of pulsed electromagnetic fields combination with estrogen on postmenopausal osteoporosis". Chin J Rehabil Theory Practice (Chin); 7: 1399, 2003.

65.Zhou QW, He PY, Chen WX, Li XB, Wu XH: "Curative effect of pulsed electromagnetic fields on senile osteoporosis patients". Fujian Med J (Chin); 28: 20, 2006.

66.Gao Y, Zhang Y: "Treatment of pulsed electromagnetic fields on primary osteoporosis". J Med Forum (Chin); 27: 59, 2006.

Volume 2 Issue 4 April 2021