Electrical stimulation enhances tissue reorganization during orthodontic tooth movement in rats

Clinical Oral Investigations

January 2017, Volume 21, Issue 1, pp 111–120 | Cite as

Original Article
First Online: 26 February 2016

Abstract

Objective

This study evaluated the effects of a low-intensity electric current on tissue reorganization during experimental orthodontic tooth movement.

Materials and methods

Thirty-two animals were divided into two groups evaluated on days 3 and 7: OTM—orthodontic tooth movement and OTM + MC—orthodontic tooth movement and microcurrent application (10 μA/5 min). The samples were processed for histological, morphometric, and Western blotting analysis.

Results

Analysis of the periodontal ligament (PL) showed a significantly smaller number of granulocytes in the OTM + MC group on day 7.The number of fibroblasts was significantly higher in the OTM + MC group on days 3 and 7. The area of birefringent collagen fibers was more organized in the OTM + MC group on days 3 and 7. The number of blood vessels was significantly higher in the OTM + MC group on day 7. Microcurrent application significantly increased the number of osteoclasts in the compression region of the PL. In the OTM + MC group on day 7 of tooth movement, the expression of TGF-β1 and VEGF was significantly reduced whereas the expression of bFGF was increased in PL.

Conclusions

Electrical stimulation enhances tissue responses, reducing the number of granulocytes and increasing the number of fibroblasts, blood vessels, and osteoclasts and modulates the expression of TGF-β1, VEFG, and bFGF.

Clinical relevance

This technique is used in many areas of medicine, but poorly explored in dentistry and orthodontics. This treatment is cheap and non-invasive and can be applied by own orthodontist, and it can improve the treatment with a faster and safe tooth movement, without pain.

Keywords

Microcurrent application   Low-intensity electric current
Orthodontic tooth movement

Notes

Compliance with ethical standards

Funding

This study was funded by the National Council for Scientific and Technological Development - CAPES/PNPD (process no. 23038.008192/2013-01) and Heminio Ometto University Center.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in the present research were in accordance with the ethical standards of the Research Ethics Committee of Herminio Ometto University Center (permit no. 095/2011) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

The studied experimental model involves animals (rats), thus informed consent is not necessary.

References

1. Van Schepdael A, Vander Sloten J, Geris L (2013) A mechanobiological model of orthodontic tooth movement. Biomech Model Mechanobiol 12:249–265
CrossRef (https://doi.org/10.1007/s10237-012-0396-5)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=22539046)
Google Scholar (http://scholar.google.com/scholar_lookup?title=A%20mechanobiological%20model%20of%20orthodontic%20tooth%20movement&author=A.%20Schepdael&author=J.%20Vander%20Sloten&author=L.%20Geris&journal=Biomech%20Model%20Mechanobiol&volume=12&pages=249-265&publication_year=2013)
2. Krishnan V, Davidovitch Z (2006) Cellular, molecular, and tissue-level reactions to orthodontic force. Am J Orthod Dentofacial Orthop 129(469):e1–32
Google Scholar (http://scholar.google.com/scholar_lookup?title=Cellular%2C%20molecular%2C%20and%20tissue-level%20reactions%20to%20orthodontic%20force&author=V.%20Krishnan&author=Z.%20Davidovitch&journal=Am%20J%20Orthod%20Dentofacial%20Orthop&volume=129&issue=469&pages=e1-32&publication_year=2006)
3. Ren Y, Vissink A (2008) Cytokines in crevicular fluid and orthodontic tooth movement. Eur J Oral Sci 116:89–97
CrossRef (https://doi.org/10.1111/j.1600-0722.2007.00511.x)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=18353001)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Cytokines%20in%20crevicular%20fluid%20and%20orthodontic%20tooth%20movement&author=Y.%20Ren&author=A.%20Vissink&journal=Eur%20J%20Oral%20Sci&volume=116&pages=89-97&publication_year=2008)
4. Krishnan V, Davidovitch Z (2009) On a path to unfolding the biological mechanisms of orthodontic tooth movement. J Dent Res 88:597–608
CrossRef (https://doi.org/10.1177/0022034509338914)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=19641146)
Google Scholar (http://scholar.google.com/scholar_lookup?title=On%20a%20path%20to%20unfolding%20the%20biological%20mecha

nisms%20of%20orthodontic%20tooth%20movement&author=V.%20Krishnan&author=Z.%20Davidovitch&journal=J%20Dent%20Res&volume=88&pages=597-608&publication_year=2009)

5. Teixeira CC, Khoo E, Tran J, Chartres I, Liu Y, Thant LM, Khabensky I, Gart LP, Cisneros G, Alikhani M (2010) Cytokine expression and accelerated tooth movement. J Dent Res 89:1135–1141
CrossRef (https://doi.org/10.1177/0022034510373764)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=20639508)
PubMedCentral (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3318047)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Cytokine%20expression%20and%20accelerated%20tooth%20movement&author=CC.%20Teixeira&author=E.%20Khoo&author=J.%20Tran&author=I.%20Chartres&author=Y.%20Liu&author=LM.%20Thant&author=I.%20Khabensky&author=LP.%20Gart&author=G.%20Cisneros&author=M.%20Alikhani&journal=J%20Dent%20Res&volume=89&pages=1135-1141&publication_year=2010)

6. Bismar H, Klöppinger T, Schuster EM, Balbach S, Diel I, Ziegler R, Pfeilschifter J (1999) Transforming growth factor beta (TGF-beta) levels in the conditioned media of human bone cells: relationship to donor age, bone volume, and concentration of TGF-beta in human bone matrix in vivo. Bone 24:565–569
CrossRef (https://doi.org/10.1016/S8756-3282(99)00082-4)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10375198)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Transforming%20growth%20factor%20beta%20%28TGF-beta%29%20levels%20in%20the%20conditioned%20media%20of%20human%20bone%20cells%3A%20relationship%20to%20donor%20age%2C%20bone%20volume%2C%20and%20concentration%20of%20TGF-beta%20in%20human%20bone%20matrix%20in%20vivo&author=H.%20Bismar&author=T.%20Kl%C3%B6ppinger&author=EM.%20Schuster&author=S.%20Balbach&author=I.%20Diel&author=R.%20Ziegler&author=J.%20Pfeilschifter&journal=Bone&volume=24&pages=565-569&publication_year=1999)

7. Garlet TP, Coelho U, Silva JS, Garlet GP (2007) Cytokine expression pattern in compression and tension sides of the periodontal ligament during orthodontic tooth movement in humans. Eur J Oral Sci 115:355–362
CrossRef (https://doi.org/10.1111/j.1600-0722.2007.00469.x)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=17850423)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Cytokine%20expression%20pattern%20in%20compression%20and%20tension%20sides%20of%20the%20periodontal%20ligament%20during%20orthodontic%20tooth%20movement%20in%20humans&author=TP.%20Garlet&author=U.%20Coelho&author=JS.%20Silva&author=GP.%20Garlet&journal=Eur%20J%20Oral%20Sci&volume=115&pages=355-362&publication_year=2007)

8. Di Domenico M, D’apuzzo F, Feola A, Cito L, Monsurrò A, Pierantoni GM,

Berrino L, De Rosa A, Polimeni A, Perillo L (2012) Cytokines and VEGF induction in orthodontic movement in animal models J Biomed Biotechnol 201689.
Google Scholar (https://scholar.google.com/scholar?q=Di%20Domenico%20M%2C%20D%E2%80%99apuzzo%20F%2C%20Feola%20A%2C%20Cito%20L%2C%20Monsurr%C3%B2%20A%2C%20Pierantoni%20GM%2C%20Berrino%20L%2C%20De%20Rosa%20A%2C%20Polimeni%20A%2C%20Perillo%20L%20%282012%29%20Cytokines%20and%20VEGF%20induction%20in%20orthodontic%20movement%20in%20animal%20models%20J%20Biomed%20Biotechnol%20201689.)

9. Salomão MFLS, Reis SRA, Vale VLC, Machado CV, Meyer R, Nascimento ILO (2014) Immunolocalization of FGF-2 and VEGF in rat periodontal ligament during experimental tooth movement. Dental Press J Orthod 19:67–74
CrossRef (https://doi.org/10.1590/2176-9451.19.3.067-074.oar)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=25162568)
PubMedCentral (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4296624)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Immunolocalization%20of%20FGF-2%20and%20VEGF%20in%20rat%20periodontal%20ligament%20during%20experimental%20tooth%20movement&author=MFLS.%20Salom%C3%A3o&author=SRA.%20Reis&author=VLC.%20Vale&author=CV.%20Machado&author=R.%20Meyer&author=ILO.%20Nascimento&journal=Dental%20Press%20J%20Orthod&volume=19&pages=67-74&publication_year=2014)

10. Derringer KA, Linden RW (2004) Vascular endothelial growth factor, fibroblast growth factor 2, platelet derived growth factor and transforming growth factor beta released in human dental pulp following orthodontic force. Arch Biol Oral 49:631–641
CrossRef (https://doi.org/10.1016/j.archoralbio.2004.02.011)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Vascular%20endothelial%20growth%20factor%2C%20fibroblast%20growth%20factor%202%2C%20platelet%20derived%20growth%20factor%20and%20transforming%20growth%20factor%20beta%20released%20in%20human%20dental%20pulp%20following%20orthodontic%20force&author=KA.%20Derringer&author=RW.%20Linden&journal=Arch%20Biol%20Oral&volume=49&pages=631-641&publication_year=2004)

11. Sako E, Hosomichi J (2010) Alteration of bFGF expression with growth and age in rat molar periodontal ligament. Angle Orthod 80:904–911
CrossRef (https://doi.org/10.2319/011910-38.1)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=20578862)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Alteration%20of%20bFGF%20expression%20with%20growth%20and%20age%20in%20rat%20molar%20periodontal%20ligament&author=E.%20Sako&author=J.%20Hosomichi&journal=Angle%20Orthod&volume=80&pages=904-911&publication_year=2010)

12. Feito MJ, Lozano RM, Alcaide M, Ramírez-Santillán C, Arcos D, Vallet-Regí M, Portolés MT (2011) Immobilization and bioactivity evaluation of FGF-1 and FGF-2 on powdered silicon-doped hydroxyapatite and their scaffolds for

bone tissue engineering. J Mater Sci Mater Med 22:405–416
CrossRef (https://doi.org/10.1007/s10856-010-4193-3)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=21132351)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Immobilization%20and%20bioactivity%20evaluation%20of%20FGF-1%20and%20FGF-2%20on%20powdered%20silicon-doped%20hydroxyapatite%20and%20their%20scaffolds%20for%20bone%20tissue%20engineering&author=MJ.%20Feito&author=RM.%20Lozano&author=M.%20Alcaide&author=C.%20Ram%C3%ADrez-Santill%C3%A1n&author=D.%20Arcos&author=M.%20Vallet-Reg%C3%AD&author=MT.%20Portol%C3%A9s&journal=J%20Mater%20Sci%20Mater%20Med&volume=22&pages=405-416&publication_year=2011)

13. Qu D, Li J, Li Y, Gao Y, Zuo Y, Hsu Y, Hu J (2011) Angiogenesis and osteogenesis enhanced by bFGF ex vivo gene therapy for bone tissue engineering in reconstruction of calvarial defects. J Biomed Mater Res 96:543–551
CrossRef (https://doi.org/10.1002/jbm.a.33009)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Angiogenesis%20and%20osteogenesis%20enhanced%20by%20bFGF%20ex%20vivo%20gene%20therapy%20for%20bone%20tissue%20engineering%20in%20reconstruction%20of%20calvarial%20defects&author=D.%20Qu&author=J.%20Li&author=Y.%20Li&author=Y.%20Gao&author=Y.%20Zuo&author=Y.%20Hsu&author=J.%20Hu&journal=J%20Biomed%20Mater%20Res&volume=96&pages=543-551&publication_year=2011)

14. Agren MS, Werthen M (2007) The extracellular matrix in wound healing: a closer look at therapeutics for chronic wounds. Int J Low Extrem Wounds 6:82–97
CrossRef (https://doi.org/10.1177/1534734607301394)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=17558006)
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20extracellular%20matrix%20in%20wound%20healing%3A%20a%20closer%20look%20at%20therapeutics%20for%20chronic%20wounds&author=MS.%20Agren&author=M.%20Werthen&journal=Int%20J%20Low%20Extrem%20Wounds&volume=6&pages=82-97&publication_year=2007)

15. Neves LMG, Matheus RL, Santos GMT, Esquisatto MAM, Amaral MEC, Mendonça FAS (2013) Effects of microcurrent application and 670 nm InGaP low-level laser irradiation on experimental wound healing in healthy and diabetic Wistar rats. Laser Phys 23:035604
CrossRef (https://doi.org/10.1088/1054-660X/23/3/035604)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20microcurrent%20application%20and%20670%C2%A0nm%20InGaP%20low-level%20laser%20irradiation%20on%20experimental%20wound%20healing%20in%20healthy%20and%20diabetic%20Wistar%20rats&author=LMG.%20Neves&author=RL.%20Matheus&author=GMT.%20Santos&author=MAM.%20Esquisatto&author=MEC.%20Amaral&author=FAS.%20Mendon%C3%A7a&journal=Laser%20Phys&volume=23&pages=035604&publication_year

=2013)

16. Campos Ciccone C, Zuzzi DC, Neves LMG, Mendonça JS, Paulo Pinto Joazeiro PP, Esquisatto MAM (2013) Effects of microcurrent stimulation on Hyaline cartilage repair in immature male rats (*Rattus norvegicus*) BMC Complement. Altern Med 13:17
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20microcurrent%20stimulation%20on%20Hyaline%20cartilage%20repair%20in%20immature%20male%20rats%20%28Rattus%20norvegicus%29%20BMC%20Complement&author=C.%20Campos%20Ciccone&author=DC.%20Zuzzi&author=LMG.%20Neves&author=JS.%20Mendon%C3%A7a&author=PP.%20Paulo%20Pinto%20Joazeiro&author=MAM.%20Esquisatto&journal=Altern%20Med&volume=13&pages=17&publication_year=2013)

17. Zuzzi DC, Ciccone CC, Neves LM, Mendonça JS, Joazeiro PP, Esquisatto MA (2013) Evaluation of the effects of electrical stimulation on cartilage repair in adult male rats. Tissue Cell 45:275–281
CrossRef (https://doi.org/10.1016/j.tice.2013.02.003)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=23648173)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Evaluation%20of%20the%20effects%20of%20electrical%20stimulation%20on%20cartilage%20repair%20in%20adult%20male%20rats&author=DC.%20Zuzzi&author=CC.%20Ciccone&author=LM.%20Neves&author=JS.%20Mendon%C3%A7a&author=PP.%20Joazeiro&author=MA.%20Esquisatto&journal=Tissue%20Cell&volume=45&pages=275-281&publication_year=2013)

18. Fujita M, Hukuda S, Doida Y (1992) The effect of constant direct electrical current on intrinsic healing in the flexor tendon in vitro. An ultrastructural study of differing attitudes in epitenon cells and tenocytes. J Hand Surg [Br] 17:94–98
CrossRef (https://doi.org/10.1016/0266-7681(92)90021-S)
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20effect%20of%20constant%20direct%20electrical%20current%20on%20intrinsic%20healing%20in%20the%20flexor%20tendon%20in%20vitro.%20An%20ultrastructural%20study%20of%20differing%20attitudes%20in%20epitenon%20cells%20and%20tenocytes&author=M.%20Fujita&author=S.%20Hukuda&author=Y.%20Doida&journal=J%20Hand%20Surg%20%5BBr%5D&volume=17&pages=94-98&publication_year=1992)

19. Lin YL, Moolenaar H, van Weeren PR, van de Lest CH (2006) Effect of microcurrent electrical tissue stimulation on equine tenocytes in culture. Am J Vet Res 67:271–276
CrossRef (https://doi.org/10.2460/ajvr.67.2.271)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=16454632)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20microcurrent%20electrical%20tissue%20stimulation%20on%20equine%20tenocytes%20in%20culture&author=YL.%20Lin&author=H.%20Moolenaar&author=PR.%20Weeren&author=CH.%20Lest&journal=Am%20J%20Vet%20Res&volume=67&pages=271-

276&publication_year=2006)

20. Martin RB, Gutman W (1978) The effect of electric fields on osteoporosis of disease. Calcif Tissue Int 5:23–27
CrossRef (https://doi.org/10.1007/BF02010747)
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20effect%20of%20electric%20fields%20on%20osteoporosis%20of%20disease&author=RB.%20Martin&author=W.%20Gutman&journal=Calcif%20Tissue%20Int&volume=5&pages=23-27&publication_year=1978)

21. Mendonça JS, Neves LMG, Esquisatto MAM, Mendonça FAS, Santos GMT (2013) Comparative study of the application of microcurrent and AsGa 904 nm laser radiation in the process of repair after calvaria bone excision in rats. Laser Phys 23:035605
CrossRef (https://doi.org/10.1088/1054-660X/23/3/035605)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Comparative%20study%20of%20the%20application%20of%20microcurrent%20and%20AsGa%20904%C2%A0nm%20laser%20radiation%20in%20the%20process%20of%20repair%20after%20calvaria%20bone%20excision%20in%20rats&author=JS.%20Mendon%C3%A7a&author=LMG.%20Neves&author=MAM.%20Esquisatto&author=FAS.%20Mendon%C3%A7a&author=GMT.%20Santos&journal=Laser%20Phys&volume=23&pages=035605&publication_year=2013)

22. Chao PH, Roy R, Mauck ML, Liu W, Valhmu WB, Hung CT (2000) Chondrocyte translocation response to direct current electric fields. J Biomech Eng 122:261–267
CrossRef (https://doi.org/10.1115/1.429661)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=10923294)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Chondrocyte%20translocation%20response%20to%20direct%20current%20electric%20fields&author=PH.%20Chao&author=R.%20Roy&author=ML.%20Mauck&author=W.%20Liu&author=WB.%20Valhmu&author=CT.%20Hung&journal=J%20Biomech%20Eng&volume=122&pages=261-267&publication_year=2000)

23. McCaig CD, Rajnicek AM, Song B, Zhao M (2005) Controlling cell behavior electrically:current views and future potential. Physiol Rev 85:943–978
CrossRef (https://doi.org/10.1152/physrev.00020.2004)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=15987799)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Controlling%20cell%20behavior%20electrically%3Acurrent%20views%20and%20future%20potential&author=CD.%20McCaig&author=AM.%20Rajnicek&author=B.%20Song&author=M.%20Zhao&journal=Physiol%20Rev&volume=85&pages=943-978&publication_year=2005)

24. Funk RH, Monsees TK (2006) Effects of electromagnetic fields on cells: physiological andtherapeutical approaches and molecular mechanisms of interaction. A review. Cells Tissues Organs 182:59–78
CrossRef (https://doi.org/10.1159/000093061)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=16804297)

Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20electromagnetic%20fields%20on%20cells%3A%20physiological%20andtherapeutical%20approaches%20and%20molecular%20mechanisms%20of%20interaction.%20A%20review&author=RH.%20Funk&author=TK.%20Monsees&journal=Cells%20Tissues%20Organs&volume=182&pages=59-78&publication_year=2006)

25. Poltawski L, Tim Watson T (2009) Bioelectricity and microcurrent therapy for tissue healing—a narrative review. Phys Ther Rev 14:104–114
CrossRef (https://doi.org/10.1179/174328809X405973)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Bioelectricity%20and%20microcurrent%20therapy%20for%20tissue%20healing%E2%80%94a%20narrative%20review&author=L.%20Poltawski&author=T.%20Tim%20Watson&journal=Phys%20Ther%20Rev&volume=14&pages=104-114&publication_year=2009)

26. Mendonça FAS, Passarini Junior JR, Esquisatto MA, Mendonça JS, Franchini CC, Santos GM (2009) Effects of the application of *Aloe vera* (L.) and microcurrent on the healing of wounds surgically induced in Wistar rats. Acta Cir Bras 24:150–155
CrossRef (https://doi.org/10.1590/S0102-86502009000200013)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=19377785)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20the%20application%20of%20Aloe%20vera%20%28L.%29%20and%20microcurrent%20on%20the%20healing%20of%20wounds%20surgically%20induced%20in%20Wistar%20rats&author=FAS.%20Mendon%C3%A7a&author=JR.%20Passarini%20Junior&author=MA.%20Esquisatto&author=JS.%20Mendon%C3%A7a&author=CC.%20Franchini&author=GM.%20Santos&journal=Acta%20Cir%20Bras&volume=24&pages=150-155&publication_year=2009)

27. De Gaspi FOG, Foglio MA, Carvalho JE, Santos GMT, Testa M, Passarini JR Jr, Moraes CP, Esquisatto MAM, Mendonça JS, Mendonça FAS (2011) Effects of the topical application of hydroalcoholicleaf extract of Oncidium flexuosum Sims. (Orchidaceae) and microcurrent on the healing of wounds surgically induced in Wistar rats. Evid Based Complement Alternat Med:1–9
Google Scholar (https://scholar.google.com/scholar?q=De%20Gaspi%20FOG%2C%20Foglio%20MA%2C%20Carvalho%20JE%2C%20Santos%20GMT%2C%20Testa%20M%2C%20Passarini%20JR%20Jr%2C%20Moraes%20CP%2C%20Esquisatto%20MAM%2C%20Mendon%C3%A7a%20JS%2C%20Mendon%C3%A7a%20FAS%20%282011%29%20Effects%20of%20the%20topical%20application%20of%20hydroalcoholicleaf%20extract%20of%20Oncidium%20flexuosum%20Sims.%20%28Orchidaceae%29%20and%20microcurrent%20on%20the%20healing%20of%20wounds%20surgically%20induced%20in%20Wistar%20rats.%20Evid%20Based%20Complement%20Alternat%20Med%3A1%E2%80%939)

28. Migliato KF, Chiosini MA, Mendonça FAS, Esquisatto MAM, Salgado HR, Santos GMT (2011) Effect of glycolic extract of *Dillenia indica* L combined with microcurrent stimulation on experimental lesions in Wistar rats. Wounds 23:111–120
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?

cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=25881357)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20glycolic%20extract%20of%20Dillenia%20indica%20L%20combined%20with%20microcurrent%20stimulation%20on%20experimental%20lesions%20in%20Wistar%20rats&author=KF.%20Migliato&author=MA.%20Chiosini&author=FAS.%20Mendon%C3%A7a&author=MAM.%20Esquisatto&author=HR.%20Salgado&author=GMT.%20Santos&journal=Wounds&volume=23&pages=111-120&publication_year=2011)

29. Castro FCB, Magre A, Cherpinski R, Zelante PM, Neves LMG, Esquisatto MAM, Mendonça FAZ, Santos GMT (2012) Effects of microcurrent application alone or in combination with topical *Hypericum perforatum* L and *Arnica montana* L on surgically induced wound healing in Wistar rats. Homeopathy 101:147–153
CrossRef (https://doi.org/10.1016/j.homp.2012.05.006)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=22818231)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20microcurrent%20application%20alone%20or%20in%20combination%20with%20topical%20Hypericum%20perforatum%20L%20and%20Arnica%20montana%20L%20on%20surgically%20induced%20wound%20healing%20in%20Wistar%20rats&author=FCB.%20Castro&author=A.%20Magre&author=R.%20Cherpinski&author=PM.%20Zelante&author=LMG.%20Neves&author=MAM.%20Esquisatto&author=FAZ.%20Mendon%C3%A7a&author=GMT.%20Santos&journal=Homeopathy&volume=101&pages=147-153&publication_year=2012)

30. Blumenthal NC, Ricci J, Breger L, Zychlinsky A, Solomon H, Chen GG, Kuznetsov D, Dorfman R (1997) Effects of low-intensity AC and/or DC electromagnetic fields on cell attachment and induction of apoptosis. Bioelectromagnetics 18:264–272
CrossRef (https://doi.org/10.1002/(SICI)1521-186X(1997)18%3A3<264%3A%3AAID-BEM10>3.0.CO%3B2-P)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9096845)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effects%20of%20low-intensity%20AC%20and%2For%20DC%20electromagnetic%20fields%20on%20cell%20attachment%20and%20induction%20of%20apoptosis&author=NC.%20Blumenthal&author=J.%20Ricci&author=L.%20Breger&author=A.%20Zychlinsky&author=H.%20Solomon&author=GG.%20Chen&author=D.%20Kuznetsov&author=R.%20Dorfman&journal=Bioelectromagnetics&volume=18&pages=264-272&publication_year=1997)

31. Watson T (2002) Current concepts in electrotherapy. Haemophilia 8:413–418
CrossRef (https://doi.org/10.1046/j.1365-2516.2002.00613.x)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=12010443)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Current%20concepts%20in%20electrotherapy&author=T.%20Watson&journal=Haemophilia&volume=8&pages=413-418&publication_year=2002)

32. Davidovitch Z, Finkelson MD, Steigman S, Shanfeld JL, Montgomery PC, Korostoff E (1980) Electric currents, bone remodeling, and orthodontic tooth movement increase in rate of tooth movement and periodontal cyclic nucleotide levels by combined force and electric current. Am J Orthod 77:33–47
CrossRef (https://doi.org/10.1016/0002-9416(80)90222-5)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=6243448)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Electric%20currents%2C%20bone%20remodeling%2C%20and%20orthodontic%20tooth%20movement%20increase%20in%20rate%20of%20tooth%20movement%20and%20periodontal%20cyclic%20nucleotide%20levels%20by%20combined%20force%20and%20electric%20current&author=Z.%20Davidovitch&author=MD.%20Finkelson&author=S.%20Steigman&author=JL.%20Shanfeld&author=PC.%20Montgomery&author=E.%20Korostoff&journal=Am%20J%20Orthod&volume=77&pages=33-47&publication_year=1980)

33. Kim DH, Park YG, Kang SG (2008) The effects of electrical current from a micro-electrical device on tooth movement. Korean J Orthod 38:337–346
CrossRef (https://doi.org/10.4041/kjod.2008.38.5.337)
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20effects%20of%20electrical%20current%20from%20a%20micro-electrical%20device%20on%20tooth%20movement&author=DH.%20Kim&author=YG.%20Park&author=SG.%20Kang&journal=Korean%20J%20Orthod&volume=38&pages=337-346&publication_year=2008)

34. Hashimoto H (1990) Effect of micro-pulsed electricity on experimental tooth movement. Nihon Kyosei Shika Gakkai Zasshi 49:352–361
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=2133892)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20micro-pulsed%20electricity%20on%20experimental%20tooth%20movement&author=H.%20Hashimoto&journal=Nihon%20Kyosei%20Shika%20Gakkai%20Zasshi&volume=49&pages=352-361&publication_year=1990)

35. Cheng N, Van Hoof H, Bockx E, Hoogmartens MJ, Mulier JC, De Dijcker FJ, Sansen WM, De Loecker W (1982) The effects of electrical currents on ATP generation, protein synthesis, and membrane transport in rat skin. Clin Orthop Relat Res 171:264–272
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20effects%20of%20electrical%20currents%20on%20ATP%20generation%2C%20protein%20synthesis%2C%20and%20membrane%20transport%20in%20rat%20skin&author=N.%20Cheng&author=H.%20Hoof&author=E.%20Bockx&author=MJ.%20Hoogmartens&author=JC.%20Mulier&author=FJ.%20Dijcker&author=WM.%20Sansen&author=W.%20Loecker&journal=Clin%20Orthop%20Relat%20Res&volume=171&pages=264-272&publication_year=1982)

36. Becker R (1985) The body electric. Willian Morrow and Co, Inc., New York
Google Scholar (http://scholar.google.com/scholar_lookup?

title=The%20body%20electric&author=R.%20Becker&publication_year=1985)

37. Basset CA (1993) Beneficial-effects of electromagnetic-fields. J Cell Biochem 51:387–393
CrossRef (https://doi.org/10.1002/jcb.2400510402)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Beneficial-effects%20of%20electromagnetic-fields&author=CA.%20Basset&journal=J%20Cell%20Biochem&volume=51&pages=387-393&publication_year=1993)

38. Cheng K, Goldman RJ (1998) Electric fields and proliferation in a dermal wound model: cell cycle kinetics. Bioelectromagnetics 19:68–74
CrossRef (https://doi.org/10.1002/(SICI)1521-186X(1998)19%3A2<68%3A%3AAID-BEM2>3.0.CO%3B2-1)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=9492161)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Electric%20fields%20and%20proliferation%20in%20a%20dermal%20wound%20model%3A%20cell%20cycle%20kinetics&author=K.%20Cheng&author=RJ.%20Goldman&journal=Bioelectromagnetics&volume=19&pages=68-74&publication_year=1998)

39. Kloth LC (2005) Electrical stimulation for wound healing: a review of evidence from in vitro studies, animal experiment, and clinical trials. Int J Low Extrem Wounds 4:23–44
CrossRef (https://doi.org/10.1177/1534734605275733)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=15860450)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Electrical%20stimulation%20for%20wound%20healing%3A%20a%20review%20of%20evidence%20from%20in%20vitro%20studies%2C%20animal%20experiment%2C%20and%20clinical%20trials&author=LC.%20Kloth&journal=Int%20J%20Low%20Extrem%20Wounds&volume=4&pages=23-44&publication_year=2005)

40. Mendonça FAS, Santos MTS, Esquissato MAM, Passos LE, Alves AA, Mendonça JS (2005) Efeito da aplicação da microcorrente após fratura. RGO 53:193–197
Google Scholar (http://scholar.google.com/scholar_lookup?title=Efeito%20da%20aplica%C3%A7%C3%A3o%20da%20microcorrente%20ap%C3%B3s%20fratura&author=FAS.%20Mendon%C3%A7a&author=MTS.%20Santos&author=MAM.%20Esquissato&author=LE.%20Passos&author=AA.%20Alves&author=JS.%20Mendon%C3%A7a&journal=RGO&volume=53&pages=193-197&publication_year=2005)

41. Lee HII, Kim MY, Kwon DR (2009) Therapeutic effect of microcurrent therapy in infants with congenital muscular torticollis. Am J Phys Med Rehabil 1:736–739
Google Scholar (http://scholar.google.com/scholar_lookup?title=Therapeutic%20effect%20of%20microcurrent%20therapy%20in%20infants%20with%20congenital%20muscular%20torticollis&author=HII.%20Lee&author=MY.%20Kim&author=DR.%20Kwon&journal=Am%20J%20Phys%20Med%20Rehabil&volume=1&pages=736-739&publication_year=2009)

42. Balakatounis KC, Angoules AG (2008) Low-intensity electrical stimulation in wound healing: review of the efficacy of externally applied currents resembling the current of injury. Eplasty 16:8–28
Google Scholar (http://scholar.google.com/scholar_lookup?title=Low-intensity%20electrical%20stimulation%20in%20wound%20healing%3A%20review%20of%20the%20efficacy%20of%20externally%20applied%20currents%20resembling%20the%20current%20of%20injury&author=KC.%20Balakatounis&author=AG.%20Angoules&journal=Eplasty&volume=16&pages=8-28&publication_year=2008)

43. Thakral G, Lafontaine J, Najafi B, Talal TK, Kim P, Lavery LA (2013) Electrical stimulation to accelerate wound healing. Diabet Foot Ankle 16:1–9
Google Scholar (http://scholar.google.com/scholar_lookup?title=Electrical%20stimulation%20to%20accelerate%20wound%20healing&author=G.%20Thakral&author=J.%20Lafontaine&author=B.%20Najafi&author=TK.%20Talal&author=P.%20Kim&author=LA.%20Lavery&journal=Diabet%20Foot%20Ankle&volume=16&pages=1-9&publication_year=2013)

44. Lee BY, Wendell K, AL-Waili N, Butler G (2007) Ultra-low microcurrent therapy: a novel approach for treatment of chronic resistant wounds. Adv Ther 24:1202–1209
CrossRef (https://doi.org/10.1007/BF02877766)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=18165202)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Ultra-low%20microcurrent%20therapy%3A%20a%20novel%20approach%20for%20treatment%20of%20chronic%20resistant%20wounds&author=BY.%20Lee&author=K.%20Wendell&author=N.%20AL-Waili&author=G.%20Butler&journal=Adv%20Ther&volume=24&pages=1202-1209&publication_year=2007)

45. Heller IJ, Nanda R (1979) Effect of metabolic alteration of periodontal fibers on tooth movement: an experimental study. Am J Orthod Dentofac Orthop 75:239–258
CrossRef (https://doi.org/10.1016/0002-9416(79)90272-0)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20metabolic%20alteration%20of%20periodontal%20fibers%20on%20tooth%20movement%3A%20an%20experimental%20study&author=IJ.%20Heller&author=R.%20Nanda&journal=Am%20J%20Orthod%20Dentofac%20Orthop&volume=75&pages=239-258&publication_year=1979)

46. Santamaria M Jr, Milagres D, Stuani AS, Stuani MBS, Ruellas ACO (2006) Initial changes in pulpal microvasculature during orthodontic tooth movement: a stereological study. Eur J Orthod 28:217–220
CrossRef (https://doi.org/10.1093/ejo/cji117)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=16675546)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Initial%20changes%20in%20pulpal%20microvasculature%20during%20orthodontic%20tooth%20movement%3A%20a%20stereological%20study&author=M.%20Santamaria&author=D.%20Milagres&author=AS.%20Stuani&author=MBS.%20Stuani&author=ACO.%20Ruellas&journal=Eur%20J%20

Orthod&volume=28&pages=217-220&publication_year=2006)

47. Dominici M (1902) Sur une methode de technique histologique appropriee a l'etude du systeme hematopoietique. Compt Rend Soc de Biol 54:221–223
Google Scholar (http://scholar.google.com/scholar_lookup?title=Sur%20une%20methode%20de%20technique%20histologique%20appropriee%20a%20l%E2%80%99etude%20du%20systeme%20hematopoietique&author=M.%20Dominici&journal=Compt%20Rend%20Soc%20de%20Biol&volume=54&pages=221-223&publication_year=1902)

48. Junqueira LCU, Bignolas G, Brentani RR (1979) Picrosirius staining plus polarization microscopy, a specific method for collagen detection in tissue sections. Histochem J 11:447–455
CrossRef (https://doi.org/10.1007/BF01002772)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=91593)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Picrosirius%20staining%20plus%20polarization%20microscopy%2C%20a%20specific%20method%20for%20collagen%20detection%20in%20tissue%20sections&author=LCU.%20Junqueira&author=G.%20Bignolas&author=RR.%20Brentani&journal=Histochem%20J&volume=11&pages=447-455&publication_year=1979)

49. Gornall AG, Bardawill CJ, David MM (1949) Determination of serum proteins by means of the Biuret reaction. J Biol Chem 177:751–766
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=18110453)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Determination%20of%20serum%20proteins%20by%20means%20of%20the%20Biuret%20reaction&author=AG.%20Gornall&author=CJ.%20Bardawill&author=MM.%20David&journal=J%20Biol%20Chem&volume=177&pages=751-766&publication_year=1949)

50. Lara VS, Figueiredo F, Silva TA, Cunha FQ (2003) Dentin-induced in vivo inflammatory response and in vitro activation of murine macrophages. J Dent Res 82:460–465
CrossRef (https://doi.org/10.1177/154405910308200611)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=12766199)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Dentin-induced%20in%20vivo%20inflammatory%20response%20and%20in%20vitro%20activation%20of%20murine%20macrophages&author=VS.%20Lara&author=F.%20Figueiredo&author=TA.%20Silva&author=FQ.%20Cunha&journal=J%20Dent%20Res&volume=82&pages=460-465&publication_year=2003)

51. Fracalossi AC, Santamaria M Jr, Consolaro MFMO, Consolaro A (2009) Experimental tooth movement in murines: study period and direction of microscopic sections. Rev Dent Press Ortod Ortop Facial 14:143–157
CrossRef (https://doi.org/10.1590/S1415-54192009000100014)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Experimental%20tooth%20movement%20in%20murines%3A%20study%20period%20and%20direction%20of%20microscopic%20sections&author=AC.%20Fracalossi&author=M.%20Santamaria&author=MFMO.%20Conso

laro&author=A.%20Consolaro&journal=Rev%20Dent%20Press%20Ortod%20Ortop%20Facial&volume=14&pages=143-157&publication_year=2009)

52. Janssens K, Dijke PT, Janssens S, Hul WV (2005) Transforming growth factor-b1 to the bone. Endocr Rev 26:743–774
CrossRef (https://doi.org/10.1210/er.2004-0001)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=15901668)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Transforming%20growth%20factor-b1%20to%20the%20bone&author=K.%20Janssens&author=PT.%20Dijke&author=S.%20Janssens&author=WV.%20Hul&journal=Endocr%20Rev&volume=26&pages=743-774&publication_year=2005)

53. Ripamonti U, Ferretti C, Teare J, Blann L (2009) Transforming growth factor-b isoforms and the induction of bone formation. J Craniofac Surg 20:1544–1555
CrossRef (https://doi.org/10.1097/SCS.0b013e3181b09ca6)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=19816294)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Transforming%20growth%20factor-b%20isoforms%20and%20the%20induction%20of%20bone%20formation&author=U.%20Ripamonti&author=C.%20Ferretti&author=J.%20Teare&author=L.%20Blann&journal=J%20Craniofac%20Surg&volume=20&pages=1544-1555&publication_year=2009)

54. Zhao L, Jiang S, Hantash BM (2010) Transforming growth factor beta1 induces osteogenic differentiation of murine bone marrow stromal cells. Tissue Eng Part A 16:725–733
CrossRef (https://doi.org/10.1089/ten.tea.2009.0495)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=19769530)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Transforming%20growth%20factor%20beta1%20induces%20osteogenic%20differentiation%20of%20murine%20bone%20marrow%20stromal%20cells&author=L.%20Zhao&author=S.%20Jiang&author=BM.%20Hantash&journal=Tissue%20Eng%20Part%20A&volume=16&pages=725-733&publication_year=2010)

55. Seifi M, Badiee MR, Abdolazimi Z, Amdjadi P (2013) Effect of basic fibroblast growth factor on orthodontic tooth movement in rats. Cell J 15:230–237
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=24027664)
PubMedCentral (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3769605)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Effect%20of%20basic%20fibroblast%20growth%20factor%20on%20orthodontic%20tooth%20movement%20in%20rats&author=M.%20Seifi&author=MR.%20Badiee&author=Z.%20Abdolazimi&author=P.%20Amdjadi&journal=Cell%20J&volume=15&pages=230-237&publication_year=2013)

56. Murakami M, Simons M (2008) Fibroblast growth factor regulation of neovascularization. Curr Opin Hematol 15:215–220
CrossRef (https://doi.org/10.1097/MOH.0b013e3282f97d98)

PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=18391788)
PubMedCentral (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2745288)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Fibroblast%20growth%20factor%20regulation%20of%20neovascularization&author=M.%20Murakami&author=M.%20Simons&journal=Curr%20Opin%20Hematol&volume=15&pages=215-220&publication_year=2008)

57. Wong VW, Crawford JD. Vasculogenic Cytokines in Wound Healing. Biomed Res Int 2013:190486
Google Scholar (https://scholar.google.com/scholar?q=Wong%20VW%2C%20Crawford%20JD.%20Vasculogenic%20Cytokines%20in%20Wound%20Healing.%20Biomed%20Res%20Int%202013%3A190486)

58. Asadi MR, Torkaman G, Hedayati M, Mofid M (2013) Role of sensory and motor intensity of electrical stimulation on fibroblastic growth factor-2 expression, inflammation, vascularization, and mechanical strength of full-thickness wounds. J Rehabil Res Dev 50:489–498
CrossRef (https://doi.org/10.1682/JRRD.2012.04.0074)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=23934870)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Role%20of%20sensory%20and%20motor%20intensity%20of%20electrical%20stimulation%20on%20fibroblastic%20growth%20factor-2%20expression%2C%20inflammation%2C%20vascularization%2C%20and%20mechanical%20strength%20of%20full-thickness%20wounds&author=MR.%20Asadi&author=G.%20Torkaman&author=M.%20Hedayati&author=M.%20Mofid&journal=J%20Rehabil%20Res%20Dev&volume=50&pages=489-498&publication_year=2013)

59. Dahl J, Li J, Bring DK, Renström P, Ackermann PW (2007) Intermittent pneumatic compression enhances neurovascular ingrowth and tissue proliferation during connective tissue healing: a study in the rat. J Orthop Res 25:1185–1192
CrossRef (https://doi.org/10.1002/jor.20390)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=17469190)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Intermittent%20pneumatic%20compression%20enhances%20neurovascular%20ingrowth%20and%20tissue%20proliferation%20during%20connective%20tissue%20healing%3A%20a%20study%20in%20the%20rat&author=J.%20Dahl&author=J.%20Li&author=DK.%20Bring&author=P.%20Renstr%C3%B6m&author=PW.%20Ackermann&journal=J%20Orthop%20Res&volume=25&pages=1185-1192&publication_year=2007)

60. Wise GE, King GJ (2008) Mechanisms of tooth eruption and orthodontic tooth movement. J Dent Res 87:414–434
CrossRef (https://doi.org/10.1177/154405910808700509)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=18434571)
PubMedCentral (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2387248)
Google Scholar (http://scholar.google.com/scholar_lookup?

title=Mechanisms%20of%20tooth%20eruption%20and%20orthodontic%20tooth%20movement&author=GE.%20Wise&author=GJ.%20King&journal=J%20Dent%20Res&volume=87&pages=414-434&publication_year=2008)

61. Bates DO (2008) Vascular endothelial growth factors and vascular permeability. Cardiovasc Res 87(2):262–271
CrossRef (https://doi.org/10.1093/cvr/cvq105)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Vascular%20endothelial%20growth%20factors%20and%20vascular%20permeability&author=DO.%20Bates&journal=Cardiovasc%20Res&volume=87&issue=2&pages=262-271&publication_year=2008)

62. Bao P, Kodra A, Tomic-Canic M, Golinko MS, Ehrlich HP, Brem H (2009) The role of vascular endothelial growth factor in wound healing. J Surg Res 153:347–358
CrossRef (https://doi.org/10.1016/j.jss.2008.04.023)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=19027922)
Google Scholar (http://scholar.google.com/scholar_lookup?title=The%20role%20of%20vascular%20endothelial%20growth%20factor%20in%20wound%20healing&author=P.%20Bao&author=A.%20Kodra&author=M.%20Tomic-Canic&author=MS.%20Golinko&author=HP.%20Ehrlich&author=H.%20Brem&journal=J%20Surg%20Res&volume=153&pages=347-358&publication_year=2009)

63. Aldridge SE, Lennard TW, Willims JR, Birch MA (2005) Vascular endothelial growth factor receptors in osteoclast differentiation and function. Biochem Biophys Res Commun 335:793–738
CrossRef (https://doi.org/10.1016/j.bbrc.2005.07.145)
PubMed (http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Abstract&list_uids=16105658)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Vascular%20endothelial%20growth%20factor%20receptors%20in%20osteoclast%20differentiation%20and%20function&author=SE.%20Aldridge&author=TW.%20Lennard&author=JR.%20Willims&author=MA.%20Birch&journal=Biochem%20Biophys%20Res%20Commun&volume=335&pages=793-738&publication_year=2005)

64. Di Alberti L, Rossetto A, Albanese M, D'Agostino A, De Santis D, Bertossi D, Nocini PF. Expression of vascular endothelial growth factor (VEGF) mRNA in healthy bone tissue around implants and in peri-implantitis Minerva Stomatol. 2013;11 [Epub ahead of print]
Google Scholar (https://scholar.google.com/scholar?q=Di%20Alberti%20L%2C%20Rossetto%20A%2C%20Albanese%20M%2C%20D%E2%80%99Agostino%20A%2C%20De%20Santis%20D%2C%20Bertossi%20D%2C%20Nocini%20PF.%20Expression%20of%20vascular%20endothelial%20growth%20factor%20%28VEGF%29%20mRNA%20in%20healthy%20bone%20tissue%20around%20implants%20and%20in%20peri-implantitis%20Minerva%20Stomatol.%202013%3B11%20%5BEpub%20ahead%20of%20print%5D)

65. Sousa TD, Del Carlo RJ, Viloria MIV (2001) Electrotherapy on the healing process in the articular surface of rabbits. Cienc Rural 31:819–824

CrossRef (https://doi.org/10.1590/S0103-84782001000500013)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Electrotherapy%20on%20the%20healing%20process%20in%20the%20articular%20surface%20of%20rabbits&author=TD.%20Sousa&author=RJ.%20Carlo&author=MIV.%20Viloria&journal=Cienc%20Rural&volume=31&pages=819-824&publication_year=2001)

66. De Angelis V (1970) Observation on the response of alveolar bone to orthodontic force. Am J Orthod 58:284–294
CrossRef (https://doi.org/10.1016/0002-9416(70)90092-8)
Google Scholar (http://scholar.google.com/scholar_lookup?title=Observation%20on%20the%20response%20of%20alveolar%20bone%20to%20orthodontic%20force&author=V.%20Angelis&journal=Am%20J%20Orthod&volume=58&pages=284-294&publication_year=1970)

Copyright information

About this article

Cite this article as:

Spadari, G.S., Zaniboni, E., Vedovello, S.A.S. et al. Clin Oral Invest (2017) 21: 111. https://doi.org/10.1007/s00784-016-1759-6

- Received 16 June 2015
- Accepted 19 February 2016
- First Online 26 February 2016
- DOI https://doi.org/10.1007/s00784-016-1759-6
- Publisher Name Springer Berlin Heidelberg
- Print ISSN 1432-6981
- Online ISSN 1436-3771

- About this journal
- Reprints and Permissions

- Published in cooperation with

German Society of Dental, Oral and Craniomandibular Sciences

- Published in cooperation with

European Federation of Conservative Dentistry

Personalised recommendations

1. Post-apoplectic reorganization of cortical areas processing passive movement and tactile stimulation – a neuromagnetic case study

   Druschky, Katrin... Stefan, Hermann

   NeuroReport (2001)

2. The effects of ipriflavone on the periodontal reorganization following experimental tooth movement in the rat

   Min, Ji-Hyun... Hwang, Hyeon-Shik

   The Korean Journal of Orthodontics (2007)

3. Cortical Stimulation Concurrent With Skilled Motor Training Improves Forelimb Function and Enhances Motor Cortical Reorganization Following

   Jefferson, S. C.... Adkins, D. L.