Rzeszów University Press 2025
ISSN 2544-1361 (online)
doi: 10.15584/ejcem.2025.1.11

http://www.ejcem.ur.edu.pl
European Journal of Clinical and Experimental Medicine
Eur J Clin Exp Med 2025; 23 (1): 70–75

ORIGINAL PAPER

Comparative evaluation of morphological and chemical characteristics of bone after performing osteotomy with a piezoelectric device, hard tissue laser, and low-speed handpiece

Vignesh Krishnaswamy [1], Jayachandran D. [1], Srilekha Gunasekaran [1], Sayeeganesh N. [1], Priya Kesavan [1], Kurinchichelvan Ramalingam [2]

[1] Department of Periodontology, Vinayaka Mission's Sankarachariyar Dental College, Vinayaka Mission's Research Foundation (Deemed to be University), Salem, Tamil Nadu, India
[2] Department of Periodontology, Indira Gandhi Institute of Dental Sciences, Sri Balaji Vidyapeeth (Deemed to be University), Puducherry, India

ABSTRACT
Introduction and aim. Osteotomy procedures play a crucial role in achieving the desired osseous contour and elimination of the pocket. Traditional instruments such as chisels, files, and rotating burs have limitations including heat generation and tissue damage. Novel instruments like piezoelectric and hard tissue lasers offer potential advantages in terms of precision and reduced tissue trauma. The aim of this study was to compare the chemical and morphological characteristics of bone surfaces after osteotomy procedures performed with three different instruments: piezoelectric, hard tissue laser, and low-speed handpiece.
Material and methods. Fifteen fresh cadaver bone specimens were randomly assigned to three groups: group A (piezoelectric), group B (hard tissue laser) and group C (low-speed handpiece). Osteotomy procedures were performed according to standardized protocols. The specimens were determined under an energy-dispersive X-ray spectroscopy.
Results. Analysis of morphological and chemical characteristics revealed significant differences in bone surface characteristics between groups. Groups A and B exhibited the smoothest surface with minimal tissue damage and microfractures. Group C showed the roughest surface with prominent microfractures and tissue damage.
Conclusion. Hard tissue laser and piezosurgery have shown better results due to greater precision as they preserved the bone morphology, with less microfracture and chemical demineralization after osteotomy preparation compared with low-speed handpiece.
Keywords. hard tissue laser, osteotomy, piezoelectric device

Introduction

Osseous surgery, particularly in periodontics, involves osteotomy and osteoplasty to remove periodontal pockets and reshape the bone to achieve a more physiological osseous contour. Traditional methods employ tools such as rongeurs, files, chisels, and rotating instruments such as steel bursts, diamond bursts, and carbide burs. However, despite their widespread use, these methods present significant challenges, including excessive heat generation, mechanical stress, and the potential for tissue necrosis, which can compromise clinical outcomes.[1,2]

The generation of heat during bone cutting with rotary instruments is a major concern, as it can lead to thermal injury of bone tissue. This risk persists even

Corresponding author: Vignesh Krishnaswamy, e-mail: vigswamy007@gmail.com

Received: 15.07.2024 / Revised: 28.08.2024 / Accepted: 12.09.2024 / Published: 30.03.2025

Krishnaswamy V, Jayachandran D, Gunasekaran S, Sayeeganesh N, Kesavan P, Ramalingam K. Comparative evaluation of morphological and chemical characteristics of bone after performing osteotomy with a piezoelectric device, hard tissue laser, and low-speed handpiece. *Eur J Clin Exp Med.* 2025;23(1):70–75. doi: 10.15584/ejcem.2025.1.11.

with the incorporation of internal cooling mechanisms into these instruments. Several studies have shown that elevated temperatures during osseous surgery can cause irreversible damage to the bone, leading to delayed healing, bone resorption, and, in some cases, implant failure.[3,4] Furthermore, the mechanical forces exerted by these tools can increase the risk of microfractures in the bone, particularly in situations involving brittle or compromised bone structures.[5]

In addition to thermal and mechanical challenges, conventional osseous surgery techniques carry the risk of injuring critical anatomical structures. For example, inadvertent damage to the Schneiderian membrane during maxillary sinus procedures or the inferior alveolar nerve during mandibular surgery can result in significant complications, such as chronic pain, altered sensation, or even permanent nerve damage.[6,7]

To address these limitations, advanced technologies such as piezoelectric devices and hard tissue lasers have been introduced into dental surgery. Piezoelectric surgery, first introduced by Vercellotti in the early 2000s, has gained popularity due to its ability to perform precise bone cuts with minimal damage to surrounding soft tissues. This technique operates through the ultrasonic vibration of a piezoelectric crystal, which generates micro-movements at the surgical tip, enabling selective bone cutting while sparing vital structures.[8] Studies have shown that piezoelectric surgery not only reduces the risk of thermal injury, but also enhances surgical precision, reduces postoperative pain, and accelerates healing compared to traditional methods.[9,10]

Laser technology has also revolutionized dental surgery and offers several advantages over conventional methods. Since the development of the ruby laser by Theodore Maiman in 1960, lasers have been increasingly used in various dental applications, including osseous surgery. Lasers provide improved visibility, hemostasis, and a relatively dry surgical field, which are particularly beneficial in periodontal procedures. The interaction of laser energy with biological tissues is wavelength-dependent, with specific tissue components, known as chromophores, absorbing wavelengths more efficiently. For example, carbon dioxide (CO_2) lasers, which operate in the infrared spectrum, are highly absorbed by water, making them effective for soft tissue procedures. However, its application in hard tissue surgery, such as bone, is limited due to the risk of excessive heat generation and subsequent thermal damage.[11,12]

Erbium-doped lasers such as the Er: Cr: YSGG lasers have emerged as viable alternatives for hard tissue applications. These lasers operate at wavelengths that are highly absorbed by both water and hydroxyapatite, the primary mineral component of bone. This selective absorption allows for precise ablation of bone tissue with minimal thermal damage, making them suitable for procedures such as osteotomy and osteoplasty. Research has shown that erbium lasers can effectively cut bone with less collateral damage, reduced postoperative inflammation, and faster healing times compared to traditional rotary instruments.[13,14]

Despite the advantages of piezoelectric devices and lasers, further research is still needed to fully understand their effects on bone morphology and chemical characteristics after osteotomy. Previous studies have focused primarily on clinical outcomes, such as healing times and complication rates, but there is a lack of comprehensive data on the microscopic and chemical changes that occur in bone tissue after these advanced surgical techniques.[15] Understanding these changes is crucial to optimize surgical protocols and improve patient outcomes in periodontal osseous surgery.

Aim

This study aims to address this gap in the literature by conducting a comparative evaluation of the morphological and chemical characteristics of bone surfaces following osteotomy using a low-speed handpiece, a hard tissue laser, and a piezoelectric device. By analyzing differences in bone surface morphology and mineral content, this research will provide valuable information on the effectiveness of these advanced technologies in preserving bone quality and promoting successful periodontal regeneration.

Material and methods

The experimental analysis was conducted on 15 newly obtained sternal sections of porcine ribs (Fig. 1), which were divided into 2 halves with sagittal osteotomy. Porcine bone is frequently utilized as a biomechanics model due to its cancellous density and cortical thickness comparable to human bone. The outer section of these bone blocks is densely cortical, while the interior portion is mainly composed of medium-density (D2–D3) trabecular bone. Before the osteotomy procedures, the bone blocks were cut into the desired size of the measurement using a hard tissue microtome (Isomet®1000 Precision Saw) with a speed of 150 Rpm (Fig. 2).

After the initial preparation of the porcine bone, they are divided into three groups for osteotomy procedures. Each group consists of 5 samples, which will be split into two halves.

- ***Piezosurgery:*** The Piezosurgery system with insert tip B1 (WandH Piezomed). The cuts were made in a horizontal direction in the bone blocks (Fig. 3A).
- ***Hard tissue laser:*** Er:Cr: YSGG (Waterlase – iPlus) was the hard tissue laser system that was used. The laser parameters were as follows: Wavelength (λ): 2780nm; Power: 3W; Frequency: 30Hz; Air: 80%; Water: 70%; Handpiece: Turbo Mx7 with a spot diameter of 700 μm and the mode used was H mode (hard tis-

sue mode) and the Waterlase turbo handpiece functioned in a non – contact mode at an optimal distance between 3 to 5 mm from the bone block (Fig. 3B).

- *Low-speed handpiece:* The low-speed handpiece system was used with 702 carbide burs with an rpm of 35,000 with the appropriate coolant (Fig. 3C).

Fig. 1. Freshly obtained sternal sections of porcine ribs

Fig. 2. Isomet® Precision saw

Fig. 3. A: WandH piezomed with B1 tip, B: Waterlase – iPlus (Turbo Mx7 handpiece with a spot diameter of 700 μm), C: Low–Speed Handpiece with 702 carbide bur

For every sample, a cross-sectional surface was selected. Scanning electron microscopy (SEM) was used in this study to analyze the surface morphology of bone tissues after osteotomy. SEM is highly effective in providing high-resolution images that reveal microstructural details of bone, such as surface roughness, porosity, and the impact of different surgical instruments on bone integrity. The technique allows for detailed visualization of how osteotomy methods alter bone surfaces, thus contributing valuable insights into the effects of surgical interventions on bone morphology. SEM has been widely used in similar studies to examine the microstructure of bone and other mineralized tissues, allowing for a complete understanding of the material's properties of the material at the microscopic level.[16]

Energy SEM combined with energy-dispersive X-ray spectroscopy (EDS) is a powerful analytical technique used to examine the surface morphology and elemental composition of materials at high resolution. When applied to bone tissue, this method allows for a precise analysis of calcium and phosphate, the primary components of hydroxyapatite, which is the mineralized matrix of bone. By detecting the characteristic X-rays emitted from these elements during SEM imaging, EDS provides quantitative and qualitative data on their distribution, enabling a detailed study of bone mineralization and composition.[17] Calcium and phosphate analysis was performed. All statistical procedures were performed using the Statistical Package for Social Sciences (SPSS, IBM< Armonk, NY, USA) 20.0. Statistical analysis was performed using one-way ANOVA test. Ethical approval was acquired from the institutional ethical committee of Vinayaka Mission Sankarachariyar Dental College IRC/24062022/S/1.

Results

Figure 4 presents the SEM images.

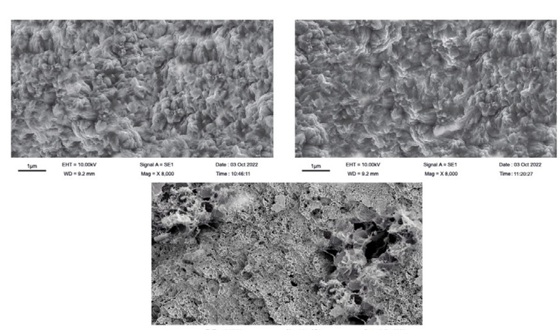

Fig. 4. SEM images of A: group I (piezoelectric), B: group II (hard tissue laser), C: group III (low-speed handpiece)

There are no morphological changes in group I (piezoelectric) and group II (hard tissue laser); group III (low-speed handpiece) shows significant changes in the bone morphology. Figure 5 shows SEM with EDS.

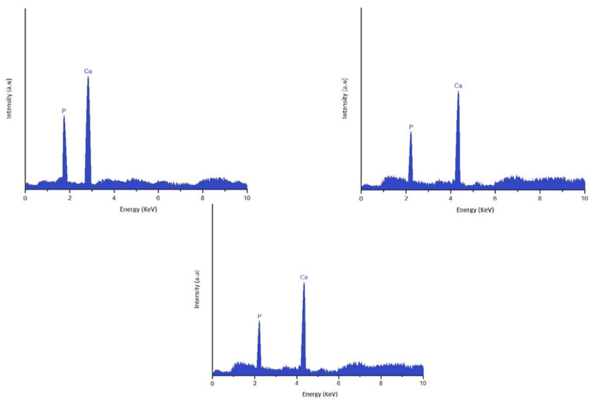

Fig. 5. EDS of A: group I, B: group II, C: group III

Table 1 denotes that the calcium particles were significantly decreased in group III (mean value=21.46) than in other groups, which signifies more calcium destruction. Both groups I and II do not have a significant reduction in calcium levels after osseous preparation.

Table 1. Comparison of calcium levels among group I(piezoelectric), group II (hard tissue laser), and group III (low-speed handpiece)

Group	n	Calcium analysis			ANOVA	p
		Mean	SD	SE		
Group I	10	24.94	0.542	0.171		
Group II	10	25.02	0.315	0.100	232.99	0.001
Group III	10	21.46	0.373	0.118		
Total	30	23.81	1.736	0.317		

Table 2 denotes that phosphate levels were significantly decreased in group III (mean value=12.51) compared to group I and II. Both groups I and II do not have a significant reduction in calcium levels after osseous preparation.

Table 2. Comparison of phosphate levels among group I (piezoelectric), group II (hard tissue laser) and group III (low-speed handpiece)

	n	Phosphate analysis			ANOVA	p
		Mean	SD	SE		
Group I	10	17.20	0.495	0.157		
Group II	10	17.27	0.624	0.197	223.61	0.001
Group III	10	12.51	0.602	0.190		
Total	30	15.66	2.331	0.426		

Discussion

This in vitro analysis assessed the ultrastructural and morphological properties of bone tissue after performing osteotomy with a piezoelectric device, hard tissue laser, and low-speed handpiece. Bone is composed of apatite crystals surrounded by an organic matrix. The EDX-SEM study exhibited that Er:Cr: YSGG ("Waterlase – iPlus") with parameters -Wavelength (λ): 2780nm; Power: 3W; frequency: 30Hz; Air: 80%; Water: 70%; handle: The 700 µm spot diameter of Turbo Mx7 is precise, with regular boundaries and sharp edges that are clearly defined for the surrounding tissue. It also shows no signs of thermal degradation. The same results were noted by Sasaki et al.[18] Furthermore, when exposing bone tissue to radiation using the Er:Cr:YSGG (Waterlase – iPlus) laser, they did not discover any regions of melting or carbonization. The microirregularities on the surface and the absence of a smear layer are the consequence of thermomechanical ablation, which is highly dependent on the energy used during radiation. Dental or bone tissues absorb nearly all the energy applied due to the 'high absorption coefficient of the Er: Cr: YSGG wavelength (2940 nm) in water along with hydroxyl ions of hydroxyapatite.[19,20] This results in an instantaneous increase in local temperature.

Water is vaporized by heat, and tissue ablation and microexplosions are produced by internal positive pressure.

Safer osteotomies and several other treatments, including ridge splitting, bone harvesting, and orthognathic and neurological surgeries, can now be carried out with the help of piezosurgery. It cuts bone selectively and does not harm soft tissue.[21] The piezosurgery device is made up of a unique piezoelectric ultrasonic transducer that can drive a variety of resonant cutting inserts. It is powered by an ultrasonic generator. With control over surgical operations in all anatomical scenarios, the piezoelectric drill's cutting action is the consequence of linear microvibrations of an ultrasonic nature, with a range between 60 µm to 200 µm in a longitudinal direction. Panduric et al. conducted a study to analyze morphological, chemical, and crystallographic changes in bone tissue after osteotomy performed with an erbium:yttrium-aluminum-garnet (Er:YAG) laser and a low-speed pilot drill. They concluded that the Er:YAG laser ablation did not cause any chemical or crystallographic changes of the bone tissue. Compared to the drill, Er:YAG laser created well-defined edges of the preparations, and the cortical bone had no smear layer.[22]

Many studies have been performed that compare the results of osteotomy performed using conventional drill systems and piezoelectric systems. Esteves et al. studied the variations between osteotomies performed with piezosurgery and a traditional drill in terms of "histomorphometrical, immunohistochemical and molecular analysis" and found that aside from a slightly greater amount of recently formed bone found 30 days after the use of the piezosurgery device, there were no differences between the bone healing from a histological and histomorphometric perspective.[23] However, in different research, Esteves et al. compared the effectiveness of a piezoelectric device with a frequently used diamond bur (DB) or carbide bur (CB), showing the healing rate of a postoperative wound in a dog model after osteoplasty and osteotomy.[24] The surgical sites treated with CB or DB showed a loss of bone relative to baseline measures, while the surgical sites treated by PS showed a degree of bone growth by the 14th day. Ercoli et al. examined the wear, heat production, durability, and cutting efficiency of implant drills in environments that simulate implant placement.[25] They concluded that cutting durability and efficiency are highly influenced by the design, material, and mechanical characteristics of drills. Implant drills can be used repeatedly without raising bone temperature to potentially dangerous levels. Deep osteotomies can develop localized temperatures that could be detrimental to the bone if the drilling is carried out continuously. Rashad et al. conducted research to assess metal attrition residues inside irrigation fluid and the structural integrity of the bone.[26] Newer sonic and ultrasonic techniques challenge traditional bur reduction. They concluded that an improvement in bone architecture was observed in sono and piezo surgery, while metal attrition was inconclusive. Piezo and sono surgery turned out to be less invasive, whereas attrition features remained the same.

In this study, it was shown that there was no significant reduction in bone calcium and phosphate levels of bone after osteotomy with piezosurgery. It is not feasible to avoid heat injury to surrounding bone tissue, even if mechanically rotating tools are equipped with an internal cooling mechanism during the process. In this study, it has been shown that the amount of calcium and phosphate is reduced in the samples in which osteotomy has been performed using a low-speed handpiece.

Conclusion

The bone did not undergo any chemical or crystallographic alterations as a result of the "Er:Cr: YSGG" laser after osteotomy. In contrast to the drill, Er:Cr: The YSGG laser produced precisely defined preparation boundaries, and the cortical bone lacked a smear layer. A relatively new surgical method called piezosurgery could be used in many different surgical procedures to supplement traditional oral surgical techniques and, in certain situations, to replace traditional procedures. It does not lead to a loss of calcium and phosphorous compared to conventional drill systems. Future research should focus on long-term healing, integration, and advanced imaging to further validate these findings. These techniques offer promising alternatives for safer and more precise bone surgery.

Acknowledgments

The authors would like to express their sincere gratitude to Vinayaka Mission's Sankarachariyar Dental College and Dr. Vidayaa Hari Iyer (Dr. Vidayaa's Smile Dental Clinic, Chennai) for her valuable contribution of the Waterlase iPlus.

Declarations

Funding

The authors have clearly stated that they have any commercial interest and financial interest. The researchers easily covered by the researchers.

Author contributions

Conceptualization, V.K. and J.D.; Methodology, V.K., J.D. and S.N.; Writing – Original Draft Preparation, V.K., J.D. and P.K.; Writing – Review & Editing, V.K., S.G., and K.R.; Supervision, J.D., S.N. and P.K.; Project Administration, J.D. and V.K.

Conflicts of interest

All authors clearly stated that they have any conflicts of interest.

Data availability

Usually, data sets are created during and/or analyzed throughout the entire study and are available from the corresponding author on reasonable request.

Ethics approval

Ethical approval was acquired from the institutional ethical committee of Vinayaka Mission Sankarachariyar Dental College IRC/24062022/S/1.

References

1. Sivolella S, Berengo M, Bressan E, Di Fiore A, Stellini E. Osteoblast-like cell behavior on granules of bioactive glass coated with poly-D, L-lactide and poly-D, L-lactide-polyethylene glycol copolymers. *J Biomed Mater Res A*. 2008;85(4):829-836.
2. Strbac GD, Giannis K, Unger E, Watzek G, Zechner W. Heat generation during different ultrasonic and conventional osteotomy techniques: an in vitro study. *Clin Oral Implants Res*. 2014;25(4):512-521.
3. Eriksson AR, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: A vital-microscopic study in the rabbit. *J Prosthet Dent.* 1983;50(1):101-107.
4. Schiegnitz E, Al-Nawas B. Narrow-diameter implants: a systematic review and meta-analysis. *J Clin Periodontol*. 2018;45(S20).
5. Giannobile WV, Lang NP, Tonetti MS. Vertical and horizontal ridge augmentation: a systematic review. *J Clin Periodontol*. 2010;37(11):203-210.
6. Misch CE, Qu Z, Bidez MW. Mechanical properties of trabecular bone in the human mandible: implications for dental implant treatment planning and surgical placement. *J Oral Maxillofac Surg*. 1999;57(6):700-706.
7. Nkenke E, Neukam FW. Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival. *Eur J Oral Implantol*. 2014;7(2).
8. Stübinger S, von Rechenberg B. Piezoelectric bone surgery: a review of the literature. *J Oral Maxillofac Surg.* 2013;71(11):2147-2153.

9. Landes CA, Ballon A, Roth C. Intraoral defect augmentation using piezosurgical split bone technique: clinical and histological long-term results. *Int J Oral Maxillofac Surg*. 2008;37(4):379-387.
10. Kim DM, Nevins ML. The use of piezosurgery to minimize trauma and post-operative complications of intraoral donor harvesting. *Dent Implantol Update*. 2007;18(12):89-95.
11. de Oliveira GJP, Marques JL. Comparative analysis of bone healing after osteotomy using piezosurgery, Er laser, and a conventional rotatory system in rabbits. *Lasers Med Sci*. 2020;35:531-540.
12. Khoshzaban A, Massoumi H, Seyyed S. Evaluation of bone healing following osteotomy with Er,Cr laser compared to conventional bur: an experimental study in rabbits. *J Lasers Med Sci*. 2015;6(3):106-112.
13. Kara C, Acar AH. Comparison of Er,Cr laser and conventional surgery in impacted tooth surgery. *Int J Oral Maxillofac Surg*. 2013;42(6):695-698.
14. Schenk RK, Willenegger H. Morphological aspects of the healing of human diaphyseal fractures. *Helv Chir Acta*. 1963;29(2):155-168.
15. Schwarz F, Becker J, Herten M. Histological evaluation of different laser devices (Er, CO2, and GaAlAs) for oral soft tissue surgery. *J Clin Periodontol*. 2007;34(8):634-640.
16. Goldstein JI, Newbury DE, Michael JR, Ritchie NWM, Scott JHJ, Joy DC. *Scanning Electron Microscopy and X-ray Microanalysis*. 4th ed. Springer; 2017. doi:10.1007/978-1-4939-6676-9.
17. Bai X, Sandukas S, Lippert F. Assessing the morphology and elemental composition of demineralized enamel by SEM and EDS. *Scanning*. 2019;2019:3272046. doi: 10.1155/2019/3272046
18. Sasaki KM, Aoki A, Ichinose S, Yoshino T, Yamada S, Ishikawa I. Scanning Electron Microscopy and Fourier Transformed Infrared Spectroscopy Analysis of Bone Removal Using Er:YAG and CO_2Lasers. *J Periodontol*. 2002;73(6):643-652. doi: 10.1902/jop.2002.73.6.643
19. Keller U, Raimund Hibst. Experimental studies of the application of the Er:YAG laser on dental hard substances: II. *Lasers Surg Med*. 1989;9(4):345-351. doi: 10.1002/lsm.1900090406
20. Hibst R, Keller U. Experimental studies of the application of the Er:YAG laser on dental hard substances: I. Measurement of the ablation rate. *Lasers Surg Med*. 1989;9(4):338-344. doi: 10.1002/lsm.1900090405
21. Chiriac G, Herten M, Schwarz FJ, Rothamel D, Becker JA. Autogenous bone chips: influence of a new piezoelectric device (Piezosurgery R) on chip morphology, cell viability and differentiation. *J Clin Periodontol*. 2005;32(9):994-999. doi: 10.1111/j.1600-051x.2005.00809.x
22. Panduric DG, Juric IB, Music S, Molčanov K, Sušic M, Anic I. Morphological and ultrastructural comparative analysis of bone tissue after Er:YAG laser and surgical drill osteotomy. *Photomed Laser Surg*. 2014 Jul;32(7):401-408. doi: 10.1089/pho.2014.3711
23. Esteves JC, Marcantonio Jr E, de Souza Faloni AP, et al. Dynamics of bone healing after osteotomy with Piezosurgery or conventional drilling– histomorphometrical, immunohistochemical, and molecular analysis. *J Trans Med*. 2013;11(1). doi: 10.1186/1479-5876-11-221
24. Vercellotti T, Nevins ML, Kim DM, et al. Osseous response following resective therapy with Piezosurgery. *Int J Periodontics Restorative Dent*. 2005;25(6):543-549.
25. Ercoli C, Funkenbusch PD, Lee HJ, Moss ME, Graser GN. The influence of drill wear on cutting efficiency and heat production during osteotomy preparation for dental implants: a study of drill durability. *Int J Oral Maxillofac Implants*. 2004;19(3):335-349.
26. Rashad A, Schwan S, Alireza Nasirpour, et al. Bone Micromorphology and Material Attrition After Sonic, Ultrasonic and Conventional Osteotomies. *In Vivo*. 2021;35(3):1499-1506. doi: 10.21873/invivo.12402