

Acceleration of Dental Movement by Photobiomodulation: How Does It Happen?

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AFTER MORE THAN 15 YEARS OF RESEARCHING, the effect of a laser on orthodontics and completing so far 30 articles on the subject, we would like with this editorial to simplify the understanding of the action mechanisms of what for many years we call laser-assisted orthodontics, and now, we must currently refer to photobiomodulation (PBM)-assisted orthodontics.

We understand that PBM precipitates a complex set of physiological interactions at the cellular level, reducing acute inflammation, relieving pain, and accelerating tissue healing. It has significant analgesic, anti-inflammatory, biostimulatory, and tissue repair effects, accelerating the processes of cell multiplication and regeneration, keeping in mind that the laser is used within the proper parameters.

Although we should note that light therapy methods based on the photochemical conversion of photo absorbing molecules are not laser-specific methods, we need to apply the most effective quality of light, this is achieved by selecting the most effective wavelength.

Although it is true that the term PBM currently encompasses various luminous systems, for the acceleration of dental movement, its mechanisms of action have been widely evaluated in an infrared diode laser. This does not mean that any light has the same biological mechanisms that can explain how it does increase dental movement speed.

From its foundation, Dr. Karu explained how its effect is achieved with specific wavelengths and how primary and secondary effects vary depending on the range of wavelength of light.

It is accepted that both absorption and scattering govern penetration of light into the tissue by molecules and structures present within the tissue. Both absorption and scattering become significantly less as the wavelength is large, so the penetration depth of near infrared (NIR) laser is maximal in the range of 810 nm.

When we talk about PBM-assisted orthodontics, it refers that this noninvasive therapy is applied during orthodontic treatment, which does not increase tissue temperature, stimulates biological functions in a dose-dependent manner, without irreversible damage, with monochromatic light. The range of its wavelength is between 780 and 830 nm (Ref.¹).

The cascade of physiological reactions resulting from applying an orthodontic force plus the laser application allows accelerating the induced dental movement up to 24–30% more speed than if we did it without PBM.

To understand how it accelerates, we must start from the basis of dental movement without looking to increase its speed by any means.

For dental movement to be allowed, the mechanism of action is explained under four fronts on which the application of force affects. An ideal acceleration technique must then affect the level of these four action fronts: blood vessels, non-mineralized tissues, mineralized tissues, and immune system.

Research in laser-assisted orthodontics has made it possible to establish that PBM affects the dental movement cells. These findings should be integrated into those previously established by applying the laser at the systemic level.

These effects are demonstrated in different regions, and the body cells are no different from those present in the jawbone and jaw. Vascular endothelium, nervous system-level reactions, defense mechanisms, and cell differentiation do not differ from the rest of the body.

When we apply PBM, we not only expect the proliferative effect at the cellular level, but other simultaneous processes that have been shown to aid inflammation control, pain, and healing some of them are increased in adenosine triphosphate, superoxide dismutase, nitric oxide levels, and nuclear factor-kappa B production.²

These complement the laser action mechanism in the acceleration of dental movement and should be understood in response to each of the four systems in which it takes effect.

The summary is shown in Fig. 1.

Effect of Laser on Blood Vessels

The laser's effects at the systemic level, vasodilation, angiogenesis, and endothelial cell proliferation have mainly been reported.

Photobiomodulation therapy (PBMT), especially at a wavelength of 808 nm, stimulated angiogenesis. Angiogenesis promoted by PBMT during orthodontic treatment has been reported even in pulp with a wavelength of 830 nm to 100 mw, 2.2 J of vestibular-applied energy, 2.2 J per palatine, for 22 sec per surface.³

Response of Nonmineralized Tissues

The response of nonmineralized tissues in dental movement focuses on collagen fibers, fibronectin, and fibroblast proliferation; besides, we must consider the expression of specific biomarkers that indicate their positive action in favoring of remodeling.

Indicators of the promotion of mechanisms needed to increase turnover in periodontal fibers are the increment of the expression of basic fibroblast growth factor (bFGF), insulin-like

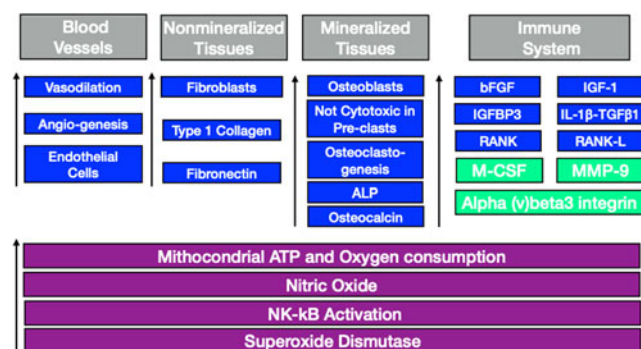


FIG. 1. Effects of PBM-assisted orthodontics. Human studies (blue), animal studies (green), and general effects of PBM (violet). ALP, alkaline phosphatase; ATP, adenosine triphosphate; bFGF, basic fibroblast growth factor; IGF-1, insulin-like growth factor-1; IGFBP3, IGF-1 receptor; IL-1 β , interleukin-1 beta; M-CSF; MMP-9; NK- κ B, nuclear factor kappa B; PBM, photobiomodulation; RANK; RANK-L; TGF, transforming growth factor.

growth factor-1 (IGF-1), IGF-1 receptor (IGFBP3), and transforming growth factor (TGF- β).⁴ At this point, the positive effects of PBM begin to overlap on the different fronts on which the application of force has its effect, for example, by achieving an increase in the expression of bFGF, which is a cytokine involved in angiogenesis, tissue remodeling, and stimulation of osteoblasts and osteoclasts.

Response of Mineralized Tissues

The action mechanisms from the different dental movement acceleration methods have been limited to this front. To better understand PBM's effect, we need to move away from the limiting concept of seeking to explain dental movement from the theory of strain-pressure. If we finally understand that, in order for the dental movement to occur, we must think of a bone remodeling process in which preosteoclasts need osteoblasts for the osteoclast genesis process; we will understand the importance of stimulating osteoblasts to promote it significantly, without affecting bone density.⁵

The PBM effect has positive results in favor of accelerating dental movement at the level of the cells involved in it and its biomarkers' expression.

In 2009, we evaluated the effect of the 830 nm laser on typical human osteoblast cultures and found a statistically significant proliferation on the 5th day compared with the control group.

This proliferation is not only necessary to achieve dental movement acceleration, but it is also required that the laser does not have a cytotoxic effect on the preclasts when applying force, leading to osteoclast genesis.⁶ The increase in osteoclastic activity, evaluated within the 5th day of force application in humans, is detectable in the urine, thanks to the increase in deoxypyridinoline, which is an indicator of bone reabsorption.

When PBM stimulates proliferation and differentiation of osteoblasts, it is accompanied by increased alkaline phosphatase and osteocalcin expression.

Nervous and Immune System Response

When applying PBM, the effects at the central nervous system level are limited to pain management.

When we apply orthodontic force and, at the same time, PBMT, we no longer consider the periodontal ligament to be the mechanotransductive organ that will allow the acceleration of dental movement. At that point, it is the bone turnover that will allow this increase in speed.

When this tissue-laser interaction occurs, increasing the proliferation of osteoblasts, we are promoting the receptor activator of NF- κ B (RANK)-receptor activator of NF- κ B ligand (RANK-L)-osteoprotegerin (OPG) system. With more osteoblasts, we will have more circulating RANK-L, and the chances of inducing osteoclast genesis will increase.

Cytokines play a crucial role in the dental movement, and the increase in their expression is consistent with an increase in movement speed. Cytokines that have been shown to have been increased in humans during PBMT in dental motion are interleukin-1 and TGF-1.

In an animal model, increments have been demonstrated in the expression of MMP-9, cathepsin K, and subunits of alpha(v)beta3 expressions. These findings suggest a favorable effect of PBM to increase the speed of dental movement.⁷

The effects of PBM anywhere in the body are understood as primary, secondary, and tertiary. The stimulating effects obtained in PBM-assisted orthodontics should be understood as multifactorial, with positive reactions in blood vessels, non-mineralized tissues, nervous system, and immune system.

References

- Domínguez Camacho A, Montoya Guzmán D, Velásquez Cujar SA. Effective wavelength range in photobiomodulation for tooth movement acceleration in orthodontics: a systematic review. *Photobiomodul Photomed Laser Surg* 2020;38:581–590.
- de Freitas LF, Hamblin MR. Proposed mechanisms of photobiomodulation or low-level light therapy. *IEEE J Sel Top Quantum Electron* 2016;22:7000417.
- Domínguez A, Ballesteros RE, Viáfara JH, Tamayo OM. Effect of low level laser therapy on dental pulp during orthodontic movement. *World J Methodol* 2013;3:19–26.
- Saygun I, Karacay S, Serdar M, Ural AU, Sencimen M, Kurtis B. Effect of laser irradiation on release of basic fibroblast growth factor(bFGF), insulin like growth factor- 1(IGF-1), and receptor of IGF-1(IGFBP3) from gingival fibroblasts. *Lasers Med Sci* 2008;23:211–215.
- Domínguez A, Velásquez SA. Reevaluation of the strain pressure theory: toward a better understanding the biology of tooth movement. *Int J Odontostomatol* 2017;11:133–140.
- Dominguez A, Morales M, Zúñiga P. Cellular effects related to the clinical uses of laser in orthodontics. *J Oral Laser Applicat* 2009;9:199–203.
- Yamaguchi M, Hayashi M, Fujita S, et al. Low-energy laser irradiation facilitates the velocity of tooth movement and the expressions of matrix metalloproteinase-9, cathepsin K, and alpha(v) beta (3) integrin in rats. *Eur J Orthod* 2010;32:131–139.

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