

## Light Emitting Diode Mediated Photobiomodulation Therapy in Orthodontics - A Review of Contemporary Literature

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### ABSTRACT

#### BACKGROUND

Photobiomodulation is an emerging area of medical and dental science that has gained attention in numerous clinical fields with the advent of new generational light - emitting diodes (LEDs), as evident in the extent of published scientific literature in recent years. The rationale behind LED - mediated photobiomodulation therapy (LPT) is that at certain biologically active wavelengths, LEDs have shown to have therapeutic effects at the cellular and subcellular levels and are an efficient alternative photon source after lasers, along with their numerous benefits.

Subsequent to favourable in-vitro, animal and recently human clinical trials, considerable attention has been garnered towards the promising applications and the integration of LPT with traditional therapeutic protocols, including in orthodontics. Originally started and accepted as a modality in acceleration of tooth movement, pain management and increasing the bone remodelling rate and quality, the advancements in this therapeutic technology have created new avenues in the treatment of temporomandibular disorders, root resorption, bone consolidation during maxillary expansion and distraction osteogenesis, as well as for improvement in miniscrew stability. Since it is non-invasive, easy to perform and user friendly with reported efficacy, an established consensus of wavelengths and parameters with respect to guidance for clinical use will go a long way in enabling the successful achievement of numerous objectives. This review article of published research intends to evaluate the adjunctive applications of LPT within orthodontic treatment at several levels along with the underlying mechanism, parameters and reported outcomes.

#### KEY WORDS

Photobiomodulation Therapy, Light Emitting Diodes, LED - Mediated Phototherapy, Low Level Light Therapy, NIR-LED, Light Accelerated Orthodontics

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## BACKGROUND

The recent past few decades have seen numerous advancements and innovations in the field of orthodontics in terms of improvement of mechanics, reduction of treatment time and methods to make it more acceptable to patients and improving their compliance. Photobiomodulation is one such modality that has witnessed considerable research interest as reflected in the current scientific literature with regard to its clinical use.<sup>1,2</sup>

Photobiomodulation therapy (PBMT) is defined as a non-invasive and non-thermal low dose light therapy based on non-ionizing light sources, including lasers (light amplification by stimulated emission of radiation), light emitting diodes (LEDs) and broadband light, in the visible and near-infrared (NIR) range (600–1000 nm).<sup>2</sup>

It generally denotes the changes in physical, chemical, and metabolic processes in target tissues<sup>3</sup> which leads to favourable therapeutic outcomes such as promotion of wound healing, mitigation of pain and inflammation, immunomodulation, improvement of blood circulation and tissue regeneration.<sup>4</sup> The term 'Photobiomodulation' is also known as and interchangeably used with 60 other names<sup>5</sup> such as 'Photobiostimulation', 'Low level light therapy', 'Phototherapy', 'Photostimulation', 'Photobioactivation', 'Photo-enhancement', 'Photoradiation', and is distinguished from other light-based sources which depend on thermal effects for their mechanism of action.<sup>6</sup> Several investigations have focused attention on mainly two sources of energy i.e. low-level lasers and LEDs.<sup>3</sup> Although lasers are popular and well-established in the photobiomodulation field, the induction of LED-mediated photobiomodulation therapy (LPT) has presented similar results in living tissues with various advantages,<sup>7</sup> thereby making them a revolution in the healthcare sector. LPT has been used with increasing popularity in medicine and dentistry and is reported to be effective in a variety of clinical indications such as reduction of pain of almost all aetiologies, improved recovery from heart ischemic injury, attenuated degeneration in the injured optic nerve, soft tissue injuries, skin rejuvenation, dermatitis, acne, hair growth, nerve regeneration in spinal cord injuries, arthritis, myopathy, in sports medicine, periodontitis, dentin hypersensitivity, osseointegration of implants, guided bone regeneration, physiotherapy and so on.<sup>5,8</sup>

In orthodontics, LPT has found multiple applications as an adjunct or as monotherapy and continues to be the subject of many in-vitro and in-vivo, animal, and lately human clinical studies. Numerous areas of clinical orthodontics have been investigated where integration of LPT has proved to be beneficial such as inhibition of orthodontically induced resorptive activity, acceleration of tooth movement, reduction of orthodontic pain, increase in alveolar bone remodelling and regeneration, in temporomandibular disorders (TMDs) along with extension over many novel clinical and experimental applications.<sup>9</sup> This article intends to provide, on the basis of existing literature, an insight into the historical development of the LPT, probable mechanism of action and how it differs from conventional lasers along with the aim to identify its applications in orthodontics and explore the answers to plausible questions that may arise to current and potential users.

## HISTORICAL BACKGROUND AND EVOLUTION OF LPT

Therapeutic use of light began when anecdotal sunlight was used in pre-historic scriptures. During the eighteenth century, the application of red and blue light for treating various human disorders including Lupus Vulgaris, was introduced by Niels Ryberg Finsen, for which he was awarded the Nobel Prize in 1903.<sup>6</sup> The next major milestone began with the invention of the first working laser by Theodore Maiman in 1960. However, there were immediate concerns about its biological safety due to its electromagnetic nature and significant destructive power.<sup>6</sup> Endre Mester, a physician from Hungary, observed that laser at low doses accelerated hair growth and promoted wound healing and termed it as 'laser biostimulation.' This led to the development of a specialized field of clinical phototherapy utilizing the low-dose light.<sup>6</sup> The field has progressed since then, with greater understanding of its underlying mechanics and investigative studies evaluating its role in management of various diseases. In 1988, Ohshiro and Calderhead gave the term 'low level laser therapy' for clinical applications and in 1992, lasers were approved by the Food and Drug Administration (FDA).<sup>8</sup> Till the 1990s, laser was the dominant energy source for phototherapy as researchers insisted that its collimated, coherent, high power density monochromatic beams were the reasons behind its therapeutic action.

Although the first visible LED was invented by Nick Holonyak Jr. in 1962, it was in 1998 when the new generational 'NASA LED' was developed by Prof Harry Whelan at the Space Medicine Laboratory, NASA for experimental plant growth in space, which offered clinicians and researchers a useful alternative photon source after lasers.<sup>5</sup>

Next through their NASA LED wound healing studies, Whelan et al. showed that useful bio-reactions could be achieved by the use of LEDs without any heat or damage through their ability of cellular photoactivation.<sup>10</sup> LPT is a relatively new phenomenon and started appearing regularly in the literature only since 2001, where focus was on the red- and near-infrared radiation and their various effects at the physiological levels.<sup>5</sup> FDA deemed NIR-LED light therapy to be a nonsignificant risk for approved use in humans<sup>11</sup> and US photobiologist, Kendrick C Smith renamed low level laser therapy as 'Low level light therapy' (LLLT) to encompass LED energy.<sup>8</sup> LPT has now gained wide acceptance as a therapeutic tool with considerable efficiency in pan-speciality disciplines without any side effects.<sup>12</sup>

## MECHANISM OF ACTION: EFFECT AT THE CELLULAR AND MOLECULAR LEVEL

In contrast to high-level light which induces varying degrees of photothermal damage by deliberately destroying a particular target, when a light source at low-incident levels of photon energy is used on tissue, all the energy is absorbed by the target cells leading to their photoactivation thereby affecting cellular metabolism, signalling and release of certain molecules, without any loss of energy as heat.<sup>8</sup>

Various mechanisms have been proposed by which biomodulatory effects on numerous cellular functions

including stimulatory and inhibitory effects in target cells are produced:

1. Stimulation of mitochondrial cytochrome c oxidase (CCO), which is the primary photo - acceptor and terminal enzyme of the cellular respiratory chain, initiates signalling pathways resulting in increased cell metabolism via ATP, Ca<sup>2+</sup> and cAMP. (Photochemical)<sup>4,11,13</sup> An increase in localized ATP bioavailability induces the remodelling process in cells by accelerating mitoses, stimulating macrophages and lymphocytes, modulating fibroblast proliferation, upregulation of transforming growth factor (TGF), keratinocyte growth factor (KGF), platelet-derived growth factor (PDGF) along with down modulation of inflammatory mediators.<sup>12,14</sup>
2. Induce the release of nitric oxide, a free radical and a negative regulator of the respiratory chain, from the CCO to further increase ATP bioavailability. When released, nitric oxide participates in regional and microvasodilation and angiogenesis.<sup>15</sup>
3. Stimulation of the release of serotonin, histamine, bradykinin and, activation of production of arachidonic acid, converting prostaglandins into prostacyclin.<sup>12,16</sup>
4. "Singlet - oxygen hypothesis", where energy deficits are removed and overall cell metabolism is raised by activation and interaction of flavoproteins and porphyrins with oxygen which results in creation of reactive singlet oxygen.<sup>3</sup>
5. "Redox properties alteration hypothesis" is another complementing hypothesis where PBMT leads to alteration of resting cellular potential towards higher oxidation and transcription factors up - regulation.<sup>3</sup>
6. PBMT - mediated augmentation of protein synthesis, synthesis and replication of RNA and DNA, and thus metabolism of cell by increasing activity of Na<sup>+</sup> / K<sup>+</sup> pump (Photophysical) and intracellular levels of Ca<sup>2+</sup>, has also been proposed.<sup>3</sup>

Regardless of the mechanism, the downstream effects of phototherapy include a modification at several stages of cell activity resulting in increased peripheral blood circulation, increased fibroblast and osteoblast proliferation, collagen and elastin synthesis, simulation of bone repair, mast cell degranulation and improved anti-inflammatory action and tissue healing.<sup>8,16,17,18</sup> These findings have prompted the use of phototherapy alone or in combination with traditional dental therapeutic approaches in periodontics, oral surgery, endodontics, restorative procedures, and more recently, orthodontics.<sup>19</sup>

**DIFFERENCE BETWEEN LOW LEVEL LASER AND LED**

Though both lasers and LED can deliver specific wavelengths at particular energy levels and their effects on tissues are similar,<sup>20</sup> however certain parameters however certain parameters differentiate them both.<sup>3,5,8,18</sup> (Table 1).

Lasers create a low-divergent, coherent, and monochromatic beam of light utilizing the 'stimulated emission' phenomenon. It leads to electron pumping of the "laser gain medium" to a state of excitation in presence of energy source.<sup>5</sup> Whereas LED sources rely on the electroluminescence phenomenon of mostly Indium - Gallium

- Nitride (InGaN) and Aluminium - Gallium - Indium - Phosphide (AlInGaP) semiconductor materials.<sup>5</sup>

Parameter	LED	Laser
Type of energy beam	Incoherent, Quasimonochromatic	Coherent, Monochromatic
Bandwidth	Wider (<10 - 20nm)	Narrow (Fraction of nm)
Specific phenomenon of light action	Photon interference	'Speckle' phenomenon
Irradiation of large areas	Possible due to large planar arrays	Limited due to point - by - point application
Side effects	Safe, no side effects	Possible
Heat production	Low	High
Device size	Small	Large
Energy consumption	Low	High
No. of clinic visits	Can be done by patient in a home setting	Multiple
Operational Cost	Low	High
Eye damage potential	No	Yes
Exposure time	Less, saves treatment time	Double time as that of LED

**Table 1. Comparison between LED and LASER**

Laser light waves are coherent spatially as well as temporally thereby facilitating light which can be focused.<sup>3</sup> Also it is difficult to reproduce combined wavelengths with lasers, and large areas are not easy to treat given the narrow beam width.<sup>11</sup>

In contrast, LEDs are incoherent in nature, permits the association of different wavelengths with the potential to be more effective and practical to uniformly deliver energy to large body surface areas, thus providing the opportunity to expand the footprint with one - time application resulting in shorter treatment duration.<sup>3,11,13,18,21,22</sup>

A fair amount of heat is emitted by lasers, thereby producing tissue damage as a potential side-effect. In contrast, LED does not release any heat, presenting as a modality that is safer and expected to cause fewer side effects if applied in a non-clinical environment. LEDs provide the same wavelengths with healing properties of light as do the lasers but through a mode of delivery which is much gentler and with a higher energy output.<sup>18</sup> Moreover, LED radiations can be generated at a lower price with the cost per mW of optical power being approximately one hundred times lower as compared to lasers.<sup>5,21</sup>

Also skin and mucosa leads to scattering of the laser beam, thereby reducing the level of its energy to a fraction of its original intensity in the range of 3 % to 6 %, <sup>23</sup> whereas the absorption coefficient of LED irradiation is low in water and haemoglobin and thus has a higher depth of penetration in the irradiated tissue, which is beneficial.<sup>13</sup> Other advantages of LED devices for use in phototherapy include smaller hardware package, lower energy density, reduced eye damage risk, the possibility of wearable devices without laser safety considerations, ease of home use supporting the clinical logistics associated with frequent applications.<sup>5,24</sup>

**APPLICATIONS OF LPT IN ORTHODONTICS**

**1. Accelerating Orthodontic Tooth Movement (OTM) - Light - Accelerated Orthodontics (LAO)**

A number of human clinical trials and animal model studies have revealed that adjunctive use of NIR - LED irradiation can significantly increase the rate of tooth movement.<sup>9,21,25-27</sup> LPT exerts a biostimulatory effect on bone tissue and enhances osteoblastic proliferation and differentiation, increases osteoclasts, activates RANK / RANKL along with rapid turnover of connective tissue cells due to higher ATP availability and increased vascular activity resulting in an

increased alveolar bone remodelling and accelerated tooth movement.<sup>21,25,28</sup> Also as reported by Nimeri et al.<sup>29</sup> this acceleration of tooth movement by LPT does not contribute to root resorption.

LPT incorporating 850nm LED has been found to significantly accelerate the mean rate of alignment thereby resulting in an average decrease of alignment phase by about 22 %<sup>30</sup> - 54 %.<sup>31</sup> It has also been observed that LPT increases the average rate of tooth movement ranging from 2.3<sup>25</sup> to 2.9 - fold,<sup>31</sup> with arches treated with LPT exhibiting a faster mean rate of alignment and reduction of total alignment duration. An experimental animal study by Ekizer et al.<sup>21</sup> using 618 nm LED found that the amount of tooth movement in the LPT treated group was much greater than the control group. Similarly, the rate of canine distalization has also been found to be increased (by 1.36-fold) by using LPT incorporating LED with 618 nm wavelength.<sup>9</sup> When used in conjunction with aligners in difficult malocclusions, LPT can be used to facilitate accelerated OTM and faster aligner changes as often as 3 - 5 days, thereby abbreviating the treatment period and improving compliance.<sup>32-35</sup>

Al - Dboush et al.<sup>34</sup> observed that adjunctive use of 850 nm LPT resulted in an average 26.6 % reduction in the clear aligner treatment duration (528 ± 323 days) as compared to the controls (719 ± 220 days).

Similarly, Dickerson et al.<sup>35</sup> noted an 84 % reduction from the conventionally recommended aligner wear time of 14 days and a 54 % reduction from the patient's own baseline (43 weeks instead of 90 weeks) in one patient and a 55 % reduction in conventional aligner change time (39 weeks instead of 84 weeks) in another patient.

## 2. Reduction of Orthodontic Post-Adjustment Pain

LPT has been found effective in decreasing the pain associated with orthodontic treatment, including even algesia associated with clear aligner therapy.<sup>36</sup> LPT using wavelengths 846 ± 20 nm<sup>37</sup> as well as 640 nm showed a significant reduction in pain sensitivity (average 56 %) and was considered even better than lasers by Esper et al.<sup>38</sup> in decreasing the pain after insertion of elastic tooth separators when compared to the non-irradiated group, thereby negating the necessity of analgesics.<sup>37</sup>

Although it has been observed that even a singular dose applied at the time of activation is beneficial in pain management, however, because of the biological tissues exhibiting multiphasic response to light, the dosimetry related with management of pain has a wider extent and higher threshold values than that associated with acceleration of tooth movement.<sup>26</sup>

The analgesic mechanisms include modulation of endogenous opioids production, direct inhibition of nerve depolarization including stabilization of membrane potential and inhibition of pain signal in peripheral nerves, reduction of prostaglandin levels, down regulation of inflammatory response proteins encoding genes along with up-regulation of genes coding for inhibition of peripheral sensory nerves.<sup>37,38</sup>

## 3. Reduction of Orthodontic Induced Inflammatory Root Resorption (OIIRR)

Studies have shown that orthodontic induced root resorption, a highly prevalent side effect,<sup>27</sup> could be significantly decreased by LED irradiation.<sup>9,21,39</sup>

In experimental animal studies by Ekizer et al.<sup>21</sup> it was found that LPT significantly led to inhibition of root resorption. Similar findings were reported by Fonseca et al.<sup>39</sup> who noted that LPT (940 nm) improved periodontal tissue repair and decreased inflammation and root resorption after the application of orthodontic force which was supplemented with positive histologic findings. Higashi et al.<sup>27</sup> in their experimental animal studies proposed that for reducing OIIRR, at least three daily sessions of 940 ± 45 nm LED therapy in the initial days after application of orthodontic forces are necessary since the key biological events of acute inflammatory response lacunae take place in the initial 72 hours.

LED acts by decreasing inflammatory mediators (TNF -  $\alpha$ , IL6) from compressed periodontium, inhibiting the receptors for osteoclast differentiation and presentation on the radicular surface along with proliferation of periodontal fibroblasts and capillaries promoting connective tissue repair,<sup>27,39</sup> and upregulation of OPG expression increasing the OPG / RANKL ratio.<sup>40</sup>

## 4. Bone Formation during Maxillary Expansion

LPT has a stimulating effect on bone formation in intermaxillary suture during orthopaedic expansion and early phase of the retention periods leading to a shorter period of retention and minimizing relapse.<sup>12</sup>

LPT potentially accelerates bone regeneration by stimulating the recruitment and / or maturation of osteoblasts from undifferentiated precursor cells along the bone edges in the expanding interpremaxillary suture, increasing collagen deposition by fibroblasts, and accelerating the mineralization of the newly formed bone by increasing hydroxyapatite deposition.<sup>12,18</sup>

As noted by Ekizer et al.<sup>12</sup> in their experimental animal study, application of 618 nm LED over the expanding suture area can increase new bone formation (1.48 - fold) in contrast to controls along with significant increase of all investigated histomorphometric parameters (osteoblasts by 1.59 - fold, osteoclasts by 1.43 - fold and vessels by 1.67 - fold). Likewise, Rosa et al.<sup>18</sup> found that LPT improves bone repair and could be an alternative to the use of laser in accelerating bone formation in the midpalatal suture.

## 5. Bone Regeneration after Distraction Osteogenesis

LPT (618 nm) application has been found to significantly accelerate bone healing along with higher bone quality (mineral density and content) and quantity of newly formed bone in distraction osteogenesis based upon radiologic and histologic evaluations. This in turn provides a clinical advantage by reducing the latent phase and speeding up the consolidation and bone maturation leading to decreased risk of infection and treatment failure.<sup>24</sup>

## 6. Miniscrew Stability

Failure of orthodontic miniscrews (3 - 19 % after loading) has often led to their removal due to their mobility after orthodontic force application.<sup>9</sup> LPT using 618 nm has been found to have a beneficial effect on attachment and stability of orthodontic miniscrews and significantly lowers the failure

rate of immediately loaded miniscrews.<sup>9,16</sup> LPT can stimulate bone regeneration around the miniscrew and affect the biologic events associated with the bone–miniscrew interface by stimulating the recruitment and / or maturation of irradiated osteoblasts along the bone edges from undifferentiated precursor cells around the miniscrew.<sup>16</sup>

### 7. Stimulation of Mandibular Growth

An experimental study by El - Bialy et al.<sup>41</sup> on growing rats reported that LED (655 nm) alone as well as LPT along with functional appliance significantly increased the fibrocartilaginous, proliferative and chondrocytic condylar layer when compared to controls, resulting in more mandibular growth stimulation in terms of bone surface area and volume. Their findings also suggested that LED is better than lasers in stimulating mandibular condyles. The possible explanation was postulated to be the laser intensity attenuation by the tissues overlying the mandibular condyle whereas LED might have maintained its original power until it reached the condyles.<sup>41</sup> The stimulatory effect is considered due to cellular and subcellular stimulation leading to fibroblastic and osteoblastic proliferation, type I collagen stimulation and angiogenesis.<sup>17,41</sup>

In another case report by El - Bialy et al.,<sup>42</sup> LPT with Clear aligner with mandibular advancement (MA) mechanism allowed to change the aligners every 3 - 4 days and after three and a half months of treatment, the profile had significantly improved by forward positioning of the mandible and chin.

### 8. Temporomandibular Disorders (TMDs)

The effectiveness of LPT in the TMD management has been demonstrated by several authors.<sup>22,43,44</sup> LPT when applied to the masticatory muscles and points around the temporomandibular joint, has been reported to relieve pain, improve range of mandibular movements, increased muscle activity and fatigue resistance in TMD patients. This effect is found with the use of 850 nm,<sup>20,44</sup> 880 nm infrared,<sup>43</sup> as well as 630 nm red<sup>20</sup> LEDs and constituted an attractive alternative for lasers.<sup>20</sup> Herpich et al.<sup>22</sup> demonstrated that even a single combined utilization of 875 nm infrared LED, 905 nm laser and 640 nm red LED resulted in reduction of masticatory muscle's pain intensity and found that this combination was effective even at varying different doses of radiation. In TMDs, LPT results in a reduction of inflammatory infiltrate in the TMJ, synovial fibroblast proliferation and a decrease in pain intensity by the downregulation of TNF -  $\alpha$ , IL - 6, cyclooxygenase (COX) enzyme and the inhibition of prostaglandin E2 as well as an increase in microcirculation around the irradiated area.<sup>22,44</sup>

### 9. Oral Ulcers Due to Fixed Orthodontic Appliances

LPT is effective in accelerating the healing of acute oral ulcers and faster clinical resolution and also in decreasing oral mucositis severity.<sup>5</sup> This is evident in both clinical and histological aspects as it leads to cell proliferation promoting epithelial lining formation along with deposition of organized collagen fibres parallel to the surface, thereby contributing to tissue remodelling and faster wound healing with reduction of pain, oedema, and inflammation.<sup>45</sup>

### 10. White Spot Lesions

Although different from LPT, antimicrobial photodynamic therapy (aPDT) utilizing blue LED (450 nm) is a promising modality for biofilm inhibition around brackets and for the prevention of white spot lesions during orthodontic treatment.<sup>46,47,48</sup>

## DOSIMETRY AND SPECIFICATIONS

In order to bring about desired effects of LPT in clinical practice, following parameters are important to reach the optimal therapeutic dose window as unsuitable intervention protocols may decrease the efficacy on target areas.<sup>37</sup>

#### 1. Wavelength

At optimal wavelengths, LED light has an approximate penetration depth of 23 cm in skin and tissue.<sup>11</sup> Optimum absorption is hampered due to incorrect wavelength, thereby ultimately affecting reaction in tissues. (Grotthuss - Draper law, first law of photobiology).<sup>8</sup> The most effective irradiation lies in the range of red to near - infrared wavelength (630–1000 nm), with 730 - 850 nm proven most competent at stimulating biological processes,<sup>3,11</sup> as haemoglobin does not absorb light in this range resulting in maximal tissue penetration.<sup>20,30</sup> Infrared LED efficiently reaches the deeper tissues making it more suitable for clinical application than the red spectrum.<sup>3,20,27</sup>

#### 2. Power / Intensity of Light / Irradiance (W / cm<sup>2</sup>)

Must be adequate for sufficient absorption of photons (5 - 50mW / cm<sup>2</sup>). However, if the intensity is too high, the photon energy will be transformed to undesirable excessive heat in the target tissue.<sup>8,36</sup>

#### 3. Energy Density / Dose / Fluence (J / cm<sup>2</sup>)

The biostimulatory effect of phototherapy follows a biphasic dose - response curve<sup>25</sup> as governed by Arndt - Schultz Law where low - moderate energy densities (2 - 5 J / cm<sup>2</sup>) can elicit stimulatory tissue response whereas higher energy densities (>20 - 25 J / cm<sup>2</sup>) result in an inhibitory effect.<sup>3,37,40</sup> Minimal energy density of 4 J / cm<sup>2</sup> at target tissue level, in the range of 2–8 J / cm<sup>2</sup> has been proven most appropriate for photobiostimulatory effects, beyond which there is progressive photobioinhibition.<sup>11,26,31,49</sup> However extending the irradiation time to compensate for low density for achieving the ideal dose of energy does not result in an adequate final outcome.<sup>8</sup>

#### 4. Mode

Pulsed method of light delivery rather than constant / continuous mode has been found to produce better results.<sup>50</sup>

#### 5. Exposure time

5 - 30 minutes per day depending upon other specifications.<sup>25,32</sup>

## 6. Clinical Site

Variation in anatomy because of the cutaneous pigmentation, biotype of covering soft tissue, cortical or trabecular density of bone and the spatial tooth position result in a diverse range of scattering and penetration depth of the photon beam which in turn affects the surface dose required to maximize the therapeutic outcome.<sup>25,26</sup> Pöntinen demonstrated that a dose of 4 J / cm<sup>2</sup> at skin level will maintain the intensity at about 0.5 – 2.5 cm of depths. When irradiating joints or muscles, a dose of 100 – 300 J / cm<sup>2</sup> was attenuated to 2 J / cm<sup>2</sup> with intensity maintained at only certain depths.<sup>20</sup>

## 7. Frequency and Duration of Treatment

Depends on the target cellular type and rate of turnover, device characteristics and disease being treated.<sup>26</sup>

## 8. Location of the Excitation Source

Extraoral units require higher power density and longer treatment times to overcome the dose threshold as soft tissue and blood absorb a percentage of incoming irradiation. Whereas with the intraoral device, the supporting periodontal tissues as well as the alveolar bone can be targeted directly and demonstrate a similar effect with the application of lower energy density and much shorter treatment sessions.<sup>31</sup>

### COMPONENTS OF VARIOUS COMMERCIALLY AVAILABLE DEVICES

Depending upon the manufacturer, the device generally consists of three main components:<sup>25,29,31</sup>

1. A controller housing the screen, software, and micro-processor, which can be programmed by an orthodontist for the treatment duration and number of applications. It indicates to the patient regarding the status of completion of sessions. The device automatically deactivates when application time is over.
2. Industry - standard LEDs arranged on a series of treatment arrays to cover the target area. For intraoral, a medical - grade silicone mouthpiece is used. For extraoral, the arrays are mounted on a contoured heat sink on a face - frame or headset similar to an eyeglass support structure.
3. Power source - Battery operated or wall mounted medically approved electric supply.

### SIDE EFFECTS

Except the rare incidence of skin irritation caused due to device material or the accidental chewing and / or swallowing of components, there are no known hazards associated with the LPT.<sup>31</sup>

### CONCLUSIONS

LPT is an innovative and non-invasive therapeutic method with well-recognized efficacy and presents a vast scope for

further explorations to devise new clinical orthodontic protocols beneficial for both clinicians and patients. The available literature indicates towards a valid modality which when carried out properly and in specific circumstances can provide multi factorial benefits and the achievement of various treatment objectives, providing numerous viable applications in clinical orthodontics without any harmful local or systematic effects. As an exciting extension of development, rigorous investigations testing the optimal parameters and variables to establish the consistency and predictability in different applications at the clinical level will permit advanced use of LPT with more general professional acceptance.

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Disclosure forms provided by the authors are available with the full text of this article at jemds.com.

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