

# Influence of low-level laser on dental implant sites: A literature review

**Abstract / Introduction:** Low-level laser therapy has been used as adjuvant in biostimulation of bone repair. **Objective:** The aim of this paper is to review studies assessing the effects of low-level laser therapy on the process of bone repair at dental implants sites. **Methods:** An electronic search of papers published between 2002 and 2013 was conducted on PubMed, Scopus and CAPES databases using the keywords “Laser therapy, Low-level”, “Phototherapy”, “Laser therapy”, and “Dental implants”. Publications structurally incomplete or not meeting the inclusion criteria were excluded. **Results:** Sixteen relevant articles were selected, fifteen of which were conducted in an animal model and one randomized clinical trial. Fourteen in vivo studies showed better bone healing in sites irradiated with low-level lasers. **Conclusion:** Low-level laser therapy seems to accelerate the process of bone repair at dental implant sites. Despite promising results obtained in studies with animal models, scientific evidence from clinical trials remains limited.

**Keywords:** Low-level laser therapy. Dental implants. Laser therapy. Phototherapy.

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## INTRODUCTION

In 1969, Implantology gained new dimensions with the evidence of osseointegration, as confirmed in the studies by Brånemark.<sup>1</sup> Since then, variations in implant placement techniques, including modifications on the surface of titanium implants<sup>2</sup> and the use of low-level laser therapy (LLLT) as adjuvant for biomodulation of bone repair, have been proposed to reduce the waiting time for load application.<sup>3</sup>

LLLT has yielded promising results regarding improvements in the bone healing process. Scientific evidence demonstrates increased mechanical strength of the bone-implant connection,<sup>4-9</sup> enhanced metabolic activity of bone cells<sup>10</sup> and expansion of angiogenesis activity at sites treated with LLLT.<sup>11</sup>

The biostimulation repair triggered by laser radiation is subject to a combination of parameters that comprise application protocols.<sup>12</sup> In addition, the effect is dependent on the dose irradiated, the method of application and the number of sessions. Together, these parameters determine the effectiveness of osteogenic cell stimulation and proliferation.<sup>9,13</sup>

Given the wide variety of study methods and laser application protocols, this study aims to review articles assessing the effects of LLLT in the biostimulation of bone repair process at implant placement sites.

## MATERIAL AND METHODS

### *Search strategy and selection of studies*

An electronic search was performed using PubMed, Scopus and CAPES databases to select studies about the effect of low-level laser therapy at implant placement sites. The search included studies published between January 2002 and October 2013. The following keywords were included in this study: laser therapy, low-level OR laser phototherapy OR laser therapy AND dental implant.

Initially, two reviewers selected the articles based on their titles and abstracts. Potential disagreements were solved by consensus after consultation with a third reviewer. After this phase, duplicate articles were excluded. Subsequently, articles were assessed according to the eligibility criteria, selected and submitted to full-text reading. Structurally incomplete or irrelevant publications were excluded from the review.

### *Eligibility criteria*

Selection criteria included: 1) original articles published in English; 2) use of statistical methods; and 3) intervention with LLLT regardless of the type of laser and application time.

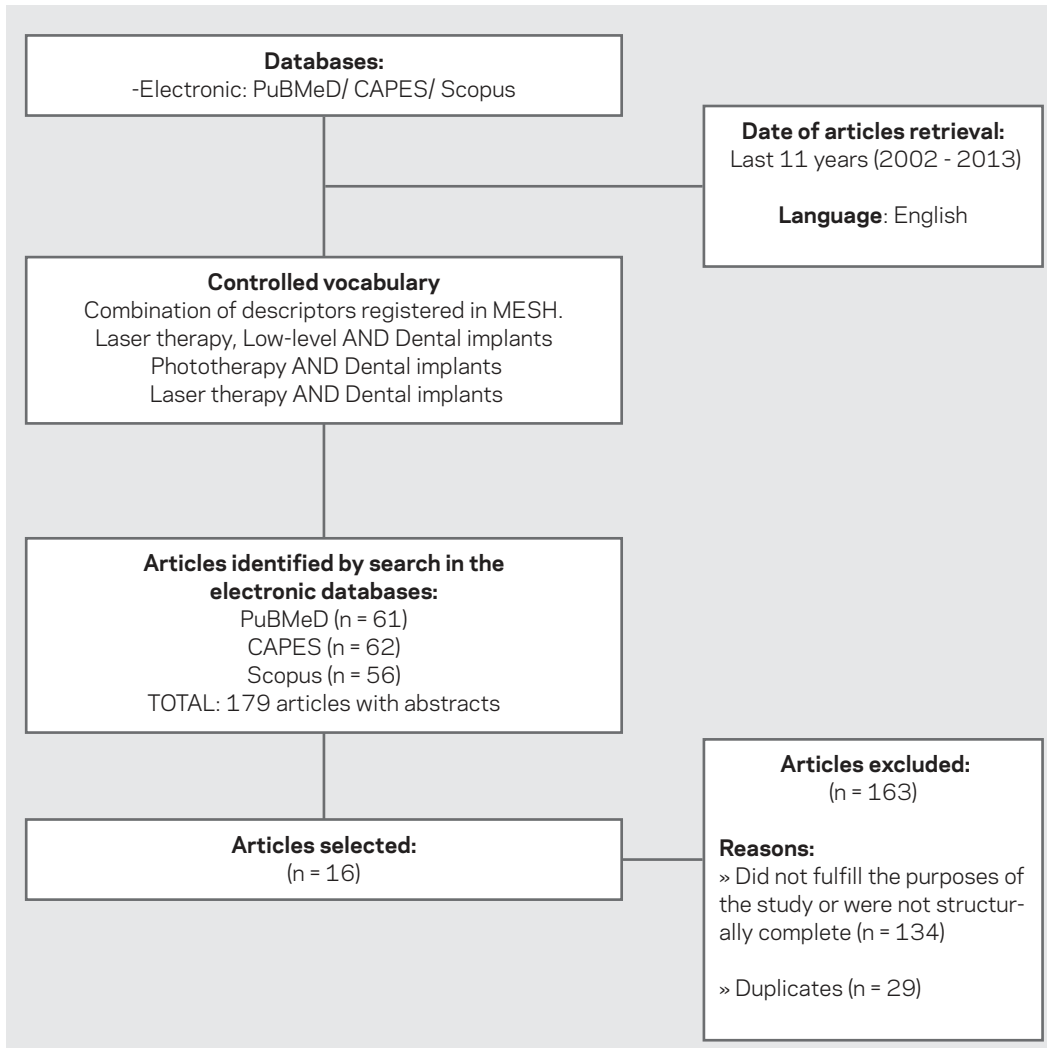
## RESULTS

After reading the titles and abstracts of 179 articles, 163 were excluded. In total, 134 articles were excluded for not fulfilling the purpose of the study or for being structurally incomplete; while 29 articles were duplicates. After this first selection, 16 articles were submitted to full-text reading and subsequently included in the review (Fig 1). The characteristics of all studies included in this research are described in Table 1.

Of the 16 articles selected, 15 studies were performed in animal models, while one study was a randomized clinical trial. A total of 14 *in vivo* studies demonstrated improvements in bone healing at sites irradiated by low-level lasers. Two studies reported no evidence of the effect produced by LLLT on peri-implant bone tissue.

## DISCUSSION

Endosseous implant treatment success depends on the potential of osteogenic cells to induce new bone formation around the implant. Therefore, LLLT has been proposed with the aim of accelerating osteoblast growth and differentiation.<sup>14</sup>



**Figure 1.** Search strategy and results.

**Table 1.** Characteristics of the studies included in the review.

Study and year of publication	Study model	Laser application protocol	Assessment method	Laser effect
Dörtbudak et al <sup>21</sup> , 2002	Baboon iliac crest	$\lambda = 690$ nm, P = 100 mw, T = 1 min. Application immediately after perforation and insertion of four implants.	Histomorphometric analysis.	Increased amount of present and viable osteocytes.
Guzzardella et al <sup>4</sup> , 2003	Rabbit femur	Laser GaAlAs, $\lambda = 780$ nm, D = 300 J/cm <sup>2</sup> , T = 1.0 min. Irradiation for 5fiveconsecutive days.	Histomorphometric and microhardness analysis.	Higher bone-implant contact.

Study and year of publication	Study model	Laser application protocol	Assessment method	Laser effect
Khadra et al <sup>5</sup> , 2004	Rabbit tibia	Laser GaAIs, $\lambda = 830$ nm, P = 150 mW, D = 23 J/cm <sup>2</sup> ; T = 20 s. Nine 3J applications for 10 consecutive days.	Removal torque; histomorphometric analysis; microanalysis by X-ray dispersive energy.	Increased value of removal torque; increased bone-implant contact; increased deposition of calcium and phosphorus.
Lopes et al <sup>23</sup> , 2005	Rabbit tibia	Laser GaAIs, $\lambda = 830$ nm, P = 10 mW, D = 85 J/cm <sup>2</sup> per session. Seven sessions at intervals of 48 hours.	Raman spectroscopy.	Increased deposition of calcium hydroxyapatite.
Jakse et al <sup>6</sup> , 2007	Sheep maxilla	$\lambda = 680$ nm, P = 75 mW, D = 3 to 4 J/cm <sup>2</sup> per session. Application after sinus graft and implant placement repeated on the 1 <sup>st</sup> , 3 <sup>rd</sup> and 7 <sup>th</sup> days postoperatively.	Histomorphometric analysis.	Higher bone-implant contact.
Kim et al <sup>10</sup> , 2007	Rat tibia	Laser GaAIs, $\lambda = 808$ nm, P = 96 mW, DP = 830 mW/cm <sup>2</sup> . Application immediately after surgery for seven consecutive days.	Immunohistochemistry.	Increased expression of vascular endothelial growth factor, stimulating angiogenesis activity.
Kim et al <sup>11</sup> , 2007	Rat tibia	Laser GaAIs, $\lambda = 808$ nm, P = 96 mW, DP = 830 mW/cm <sup>2</sup> . Application immediately after surgery for seven consecutive days.	Immunohistochemistry.	Increased metabolic activity of the bone and bone cells.
Lopes et al <sup>24</sup> , 2006	Rabbit tibia	Laser GaAIs, $\lambda = 830$ nm, P = 10 mW, D = 86 J/cm <sup>2</sup> per session. Seven sessions at 48-hour intervals.	Raman spectroscopy.	Improved bone healing, increased deposition of calcium hydroxyapatite.
Pereira et al <sup>7</sup> , 2009	Rabbit tibia	Laser GaAIs, $\lambda = 780$ nm, D = 7.5 J/cm <sup>2</sup> , T = 10s at each point. Irradiations were repeated every 48 hours for 14 days.	Histomorphometric analysis.	Increased bone-implant contact.
Campanha et al <sup>19</sup> , 2010	Rabbit tibia	Laser GaAIs, $\lambda = 830$ nm, P = 10 mW, D = 21.5 J/cm <sup>2</sup> , T = 51 s per point. Seven sessions at 48-hour intervals.	Removal torque.	Promotes osseointegration of implants with poor initial stability.
Maluf et al <sup>8</sup> , 2010	Rat tibia	Laser GaAIs, $\lambda = 795$ nm, D = 48 J/cm <sup>2</sup> . Six laser applications at 48-hour intervals.	Removal torque.	Increases bone-implant fixation.

Naka e Yokose et al <sup>22</sup> , 2011	Rat tibia	Laser CO <sub>2</sub> , $\lambda = 10.6 \mu\text{m}$ , D = 220,4 J/cm <sup>2</sup> . Irradiation before implant anchorage surgery.	Removal torque and histomorphometric analysis.	Induces bone formation and facilitates bone integration of titanium implants.
García-Morales et al <sup>18</sup> , 2012	Humans	Laser GaAlAs, $\lambda = 830 \text{ nm}$ , P=86 mW, D = 92.1 J/cm <sup>2</sup> , T = 3 s per point. Application in the immediate postoperative period and repeated every 48 hours for the first 14 days.	Analysis of resonance frequency.	No evidence for the effect of LLLT on implant stability was found.
Vasconcellos et al <sup>12</sup> , 2013	Rat femur	Laser GaAlAs, $\lambda = 780 \text{ nm}$ , P = 40 mW, D = 112 J/cm <sup>2</sup> , T= 1 min and 40 s. Irradiation in the immediate postoperative period and repeated for two weeks.	Histomorphometric analysis.	Improves the osseointegration process in normal bone and bone with osteo- penia, especially in the initial phase of bone formation.
Boldrini et al <sup>9</sup> , 2013	Rat tibia	Laser GaAlAs, $\lambda = 808 \text{ nm}$ , P = 50 mW, D = 11 J/cm <sup>2</sup> , T = 1 min and 23 s. Two applications performed immediately after preparation of the implant site.	Removal torque.	Increased bone formation at the bone-implant interface.
Primo et al <sup>20</sup> , 2013	Rat femur	Laser GaAlAs, $\lambda = 830 \text{ nm}$ , D = 4.8 J/cm <sup>2</sup> , applied immediately after implant placement.	Removal torque.	Laser therapy did not improve the interface strength of smooth implants compared with rough implants.

$\lambda$  = wavelength; P: potency; D: Energy density; DP: power density; T: irradiation time.

*In vitro* studies investigating the effect of LLLT on human osteoblasts cultured on titanium evinced increased cell adhesion,<sup>14</sup> proliferation,<sup>14,15</sup> differentiation,<sup>14,16</sup> as well as increased osteocalcin and transforming growth factor  $\beta$ 1 (TGF- $\beta$ 1) synthesis. These results support the stimulating effect and dose-dependent ability of LLLT

to accelerate cell activity, thus modulating the healing process and quality of bone formation in the peri-implant area.<sup>14</sup>

Clinical and experimental results of biomodulation with LLLT rely on the adoption of appropriate methods of stimulation.<sup>17</sup> However, no standard protocol for LLLT use in Implantology was identified in

the studies analyzed. Wide variation in the choice of wavelength and energy density was observed in the irradiation of peri-implant bone tissue.

Despite extensive protocol variability, the wavelength of experiments revised herein were within the infrared spectrum, which is characterized by low absorption coefficients and greater potential for penetration into the tissue. Thus, osteogenic cells are better able to absorb laser energy at these wavelengths.<sup>12,18</sup>

Different study methods were employed to assess the efficacy of LLLT on implant anchorage sites with a view to elucidating the effects of laser on osseointegration. Biomechanical removal torque tests were used to assess the shear strength at the bone-implant interface and provide a correlation between the force required to remove an implant and the degree of contact with the bone.<sup>8,9,19,20</sup>

Numerous studies have identified morphological changes in the peri-implant region based on histomorphometric analyses.<sup>4-7,12,21,22</sup> Other researches have used immunohistochemical analyses to verify the expression of biomarkers in active bone remodeling and the metabolic activity of bone after irradiation with LLLT.<sup>10,11</sup>

Information on the chemical composition and structure of the implant-bone interface were collected in some experiments by means of the Raman spectroscopic method.<sup>23,24</sup> In addition, less invasive techniques, such as resonant frequency analyses, were used in clinical research to obtain reliable measurements of implant stability and osseointegration.<sup>18</sup>

### **Removal torque**

Based on the removal torque values of implants anchored in bone tissue of animal

models, some studies demonstrated that laser therapy improved patients' peri-implant bone healing.<sup>8,9,19,20</sup>

The use of laser therapy in cases with reduced chances of successful osseointegration, including implant anchorage with lower initial stability, improved the bone-implant interface, especially in the early stages of healing (between 15 and 30 days).<sup>19</sup>

The dynamics of bone healing around implants treated with a single session of LLLT during surgery had the most enhanced bone formation at the bone-implant interface, especially in the final period of healing (between 30 and 45 days).<sup>9</sup>

Another benefit of laser therapy is the secondary stability of implants. It is suggested that LLLT can biomodulate bone repair, generating increased intracellular ATP and consequent increase in cellular metabolism. These mechanisms are attributed to increased osteoblastic activity in the irradiated groups.<sup>8</sup>

### **Histomorphometric analysis**

Studies using histomorphometric analyses revealed that groups treated with LLLT displayed increased bone-implant contact,<sup>4-7,22</sup> enhanced bone maturation,<sup>4</sup> and increased viable osteocytes in the irradiated bone. These results suggest that reactive and vital bone is produced at the interface with the implant, potentially resulting in a reduced healing period.<sup>21</sup>

Khadra et al<sup>5</sup> demonstrated the positive role of LLLT in improving bone healing at the interface with the implant. Their results reveal increased removal torque at irradiated sites, which might be associated with increased metabolic rates and a subsequent rapid healing process. Histomorphometric analyses revealed increased

bone-implant contact in the group treated with LLLT. In microanalyses by X-ray dispersive energy, significant increases in calcium and phosphorus were noted on implant surfaces after tensile tests. This can be explained by the accelerated differentiation of osteoblasts after irradiation.

In a study on the influence of LLLT over osseointegration of implants installed in normal and osteopenic bone, the authors reported that although osteoporosis impairs initial bone remodeling, the histomorphometric analysis revealed that LLLT revealed inductive effects, minimized the undesirable side effects of osteoporosis, and stimulated bone integration at the initial stage of healing in both conditions, in addition to increasing bone formation under normal bone metabolism conditions.<sup>12</sup>

The satisfactory results obtained by histomorphometric analyses in experimental studies suggest that laser radiation can serve as a viable noninvasive therapy that improves bone repair, given its therapeutic benefit in implants osseointegration.<sup>7,22</sup>

### **Immunohistochemical analysis**

The metabolic activity of bone after irradiation with LLLT increased, which reflects improved bone healing around the implant. In a study on the effect of LLLT on implant placement factors and the expression of RANK, RANKL and osteoprotegerin (OPG) factors for osseointegration, the authors observed increased expression of the three mediators during repair of the bone-implant interface, which promoted increase metabolic activity of the bone and increased bone cell activity. In addition, bone density in the group treated with LLLT was enhanced compared with the control.<sup>10</sup>

The expression of vascular endothelial growth factor (VEGF) in peri-implant bone remodeling was also investigated by immunohistochemical analysis. The biostimulatory effect of LLLT increased VEGF expression by stimulating angiogenesis on the surface around the implant, which is essential for bone repair.<sup>11</sup>

### **Raman spectroscopy**

The deposition of calcium hydroxyapatite (CHA) was measured by Raman spectroscopy in *in vivo* experiments. Based on these values, some studies reported that photobiomodulation with LLLT was effective in improving osseointegration, thereby resulting in increased deposition of CHA, which is indicative of increased bone maturation and resistance.<sup>23,24</sup>

The increased deposition of CHA was evidenced in the final stages of healing, suggesting that the initial phase of repair is characterized by osteoblast proliferation and minimal mineral deposition. LLLT promoted early maturation of osteoblasts and, thus, enhanced their ability to secrete hydroxyapatite. The clinical implications of these results underscore the possibility of reducing the loading time of implants at sites treated with LLLT.<sup>23,24</sup>

### **Analysis of resonance frequency**

Although some studies<sup>8,19</sup> have indicated that LLLT improves the interface between bone and implants with low initial stability, other studies reported no evidence of the effect of laser irradiation on implant stability.<sup>18</sup>

In a randomized clinical trial conducted to assess initial implant stability after LLLT, the resonance frequency of the quotient of initial implant stability of both

irradiated groups did not differ from the control, thereby resulting in normal bone healing. However, the laser effect might have been masked by the high initial stability attributed to the quality of the bone into which the implants were anchored (type II). The authors have reported that high initial stability, the geometry of the implant, and good bone quality are more relevant to the bone-implant interface than any additional therapeutic effort.<sup>18</sup>

## CONCLUSION

Based on the articles analyzed herein, it is reasonable to assert that LLLT seems to speed up the process of bone repair at implant installation sites. Despite the promising results yielded from studies carried out in animal models, few clinical studies involving humans were found in the literature. Therefore, further randomized clinical trials are warranted to assess the efficacy of LLLT in bone healing.



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