Original Article

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Dentistry Section

Synergistic Effects of Photobiomodulation and Surgical Corticotomy on Accelerated Orthodontic Tooth Movement: A Prospective Clinical Study on Canine Retraction

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ABSTRACT

Introduction: Prolonged orthodontic treatment often leads to patient discomfort and reduced compliance, necessitating faster approaches. Corticotomy surgery promotes quicker tooth movement by stimulating localised bone remodeling. Photobiomodulation (PBM), a non-invasive light therapy, enhances cellular function and healing. Their combined application may offer a synergistic effect in accelerating canine retraction during orthodontic therapy. The present study was conducted based on the rationale that combining PBM with corticotomy may produce a synergistic effect, further accelerating tooth movement and potentially reducing overall treatment duration.

Aim: To investigate the combined effects of PBM therapy and surgical corticotomy on accelerating orthodontic tooth movement, focusing on the extent and rate of canine retraction.

Materials and Methods: The present prospective split-mouth clinical study was conducted between January and September 2024 at Saveetha Dental College, Chennai, Tamil Nadu, India, with 15 patients aged 18-35 years. Fifteen patients indicated for bilateral first premolar extractions in both arches to manage crowding, with intact canines, second premolars, and first molars, good periodontal health, and plaque and gingival index scores of 0.1-0.9 and 0.1-1.0 respectively, were included. Each of the 15 patients had one side (test side) treated with PBM and surgical corticotomy, while the other side (control side) received only surgical corticotomy. Canine retraction was measured at 4, 8, and 12 weeks using intraoral scans, and the extent and rate of movement were statistically analysed using independent t-tests, and one-way repeated measures Analysis of Variance (ANOVA). A p-value below 0.05 was deemed statistically significant.

Results: The test group showed significantly greater canine retraction at 4 weeks (2.5±0.3 mm vs. 1.5±0.2 mm, p=0.005), 8 weeks (4.8±0.4 mm vs. 3.0±0.3 mm, p=0.003), and 12 weeks (6.3±0.5 mm vs. 4.0±0.4 mm, p=0.008) compared to the control group. The retraction rate was significantly higher in the test group across all monthly intervals (p<0.05).

Conclusion: PBM therapy in conjunction with surgical corticotomy significantly accelerates the extent and rate of canine retraction, suggesting its potential as an effective adjunct in orthodontic treatment.

Keywords: Laser therapy, Low-level laser therapy, Orthodontic treatment

INTRODUCTION

Orthodontic treatment often requires prolonged periods to achieve desired tooth movements, which can be a significant burden for patients and clinicians alike. Traditional approaches to accelerate Orthodontic Tooth Movement (OTM) have included mechanical and surgical methods. Among these, surgical corticotomy has gained attention for its ability to enhance the speed of OTM by temporarily reducing bone density, thereby facilitating easier tooth displacement [1]. This surgical intervention triggers a localized inflammatory response known as the Regional Acceleratory Phenomenon (RAP), which enhances bone remodeling and temporarily reduces bone density, thereby facilitating quicker and more efficient tooth repositioning [2]. The procedure involves making small gingival incisions to access the bone, creating targeted cuts, and then suturing the incisions [3].

The Periodontally Accelerated Osteogenic Orthodontics (PAOO) technique is one such method that incorporates selective alveolar decortication with bone grafting, aiming to expedite OTM through the RAP [4,5]. RAP is a biological response wherein the healing process is accelerated due to increased cellular activity and bone turnover following surgical insult. This phenomenon significantly enhances the rate of tooth movement and reduces overall treatment time, making it a valuable tool in orthodontic practice [6]. While corticotomy offers the advantage of significantly reduced treatment times and improved outcomes for complex tooth movements, it is an invasive technique with inherent risks such as infection and postoperative discomfort. Its success relies heavily on careful patient selection and the surgeon's expertise [7].

In recent years, Photobiomodulation (PBM) has emerged as a promising adjunctive therapy in dentistry [8-10]. PBM involves the use of low-level lasers or Light-emitting Diodes (LEDs) to modulate cellular activity and promote tissue repair and regeneration [11]. Studies have demonstrated that PBM can enhance bone remodeling and reduce treatment time in orthodontic procedures [12,13]. The non-invasive nature of PBM, coupled with its potential to minimize discomfort and expedite treatment, makes it an attractive option for both patients and practitioners.

The synergistic application of photobiomodulation with surgical corticotomy presents an innovative approach to orthodontic treatment. This combination aims to leverage the benefits of both techniques, potentially offering a more effective and efficient means of achieving rapid tooth movement [14]. By examining the efficacy of this combined approach, its potential to revolutionize orthodontic practices and improve patient outcomes can be better understood. The present study aimed to evaluate the efficacy of PBM when combined with surgical corticotomy in enhancing the extent and rate of orthodontic tooth movement. The alternate hypothesis posits that the combined approach significantly improves tooth movement compared to corticotomy alone, while the null hypothesis states that PBM does not offer any significant additional benefit over corticotomy alone.

MATERIALS AND METHODS

The present prospective clinical study was conducted in the Department of Periodontics, Saveetha Dental College and Hospitals, Chennai, Tamil Nadu, India, between January and September 2024. The present study utilised a split-mouth design involving 15 patients aged 18-35 years. Every participant acknowledged their voluntary involvement in the study by signing a consent form, and the Institutional Ethical Committee evaluated and approved the protocol (SRB/SDC/PERIO-2205/24/342).

Sample size calculation: The sample size was calculated based on the rate of canine movement (1.43±1.18 mm) at the fourth month, as reported in a previous study [15], using G*Power software. 80% power and significance level of 0.05 were chosen. 15 patients were the intended sample size.

Inclusion and Exclusion criteria: Fifteen patients necessitating extractive orthodontic treatment, with indications warranting the removal of the first premolars in both the upper and lower arches to address dental crowding, were included in the study. Each participant underwent the standard orthodontic diagnostic protocol, encompassing the gathering and assessment of clinical and radiographic data, along with orthopantomograms, lateral cephalometric radiographs, intraoral arch scans, and both intraoral and extraoral photographic records.

The inclusion criteria for patient selection encompassed the requirement for bilateral extraction of the first premolars in both the upper and lower arches to facilitate sufficient space for proper arch alignment. Eligible participants were also required to have intact canines, second premolars, and first permanent molars within the dental arch, along with overall good periodontal health. Only individuals with Silness and Loe plaque index scores [16] ranging from 0.1 to 0.9 and gingival index scores between 0.1 and 1.0 were considered. Patients with systemic illnesses or those undergoing pharmacological treatments that could potentially interfere with orthodontic tooth movement, such as the use of analgesics or anti-inflammatory medications were excluded from the study.

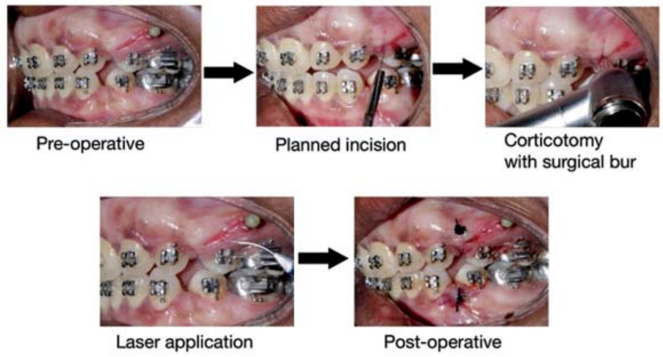
Study Procedure

Orthodontic protocol: Before performing a surgical corticotomy, a well-structured orthodontic protocol is essential to prepare the dentition and surrounding tissues for accelerated tooth movement in both the experimental and control sides. Initially, two weeks after the extractions, fixed orthodontic appliance, typically 0.022”×0.028” brackets (Ormco Corporation, Orange, CA, US), were bonded to all teeth, and a round Nickel-Titanium (NiTi) wire (0.014” or 0.016”) was used. This alignment and levelling phase, lasting 5-6 months depending on the severity of malalignment, gradually progresses to a passive rectangular Stainless Steel (SS) (0.019”×0.025”) to stabilise the dentition for retraction.

The participants enrolled in the present study were even, after following this standard protocol, if the canine retraction was not effectively achieved. The patients, having been thoroughly informed about the potential risks and anticipated benefits of the experimental protocol, agreed to take part in the study by providing their written consent. Each patient’s (n=15) mouth was divided into two halves: left maxillary and mandibular arch (test side; n=30) received both PBM and surgical corticotomy (group 1), while the right maxillary and mandibular arch (control side; n=30) received surgical corticotomy alone (group 2).

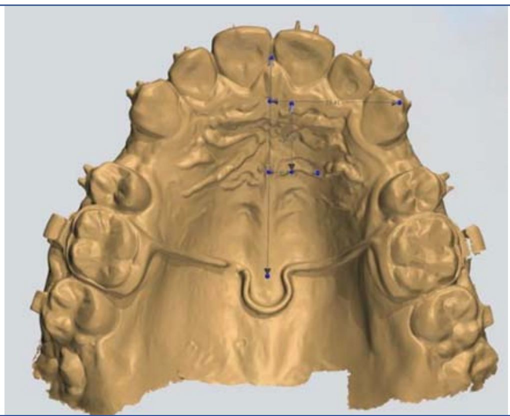
Intervention: Under local anaesthesia, all patients underwent surgical corticotomy on both sides of the mouth. This involved making small gingival incisions to expose the cortical bone, followed by precise cortical bone cuts using a surgical bur, and suturing the incisions.

On the experimental side, PBM therapy (810 nm wavelength, 100 mW power, 60 seconds per site) [17] with Zolar dental diode laser (Photon Series, Ontario, Canada) was administered immediately post-corticotomy and three more laser activations were performed, with one each on days 3, 7, and 14 for 2 to 3 minutes targeting the gingival tissues adjacent to the corticotomy sites as shown in the [Table/Fig-1].



[Table/Fig-1]: Sequential steps involved in photobiomodulation-assisted corticotomy.

Standard orthodontic appliances were placed, applying continuous light forces for canine retraction. Patients were recalled on 4, 8, and 12 weeks for follow-up appointments, where intraoral scan using 3Shape scanner was taken to assess the extent and rate of canine retraction and was then compared with baseline. The extent and rate of canine retraction were measured using the method utilised in the previous study [18]. On the scanned images, reference lines included the midpalatal raphe (serving as the midline) and a palatal ruga line extending from the midpoint of the right third palatal ruga. To assess the extent of canine retraction, a perpendicular line was drawn from the midpoint of the right third palatal ruga to the midline, along with another perpendicular line from the canine cusp tip. The linear distance between these two lines [18] represented the extent of canine movement [Table/Fig-2].



[Table/Fig-2]: Measurement of canine retraction using intraoral scan image.

STATISTICAL ANALYSIS

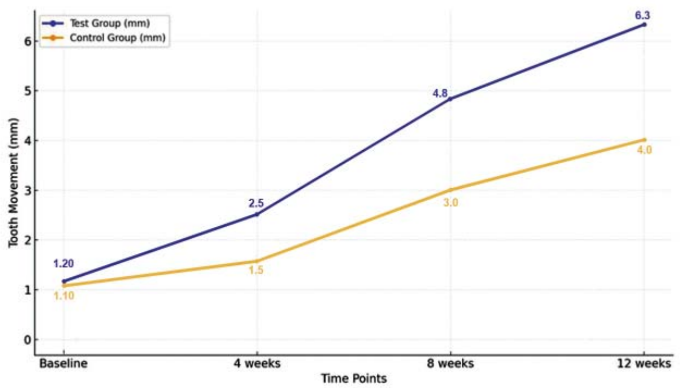
The data were processed using the Statistical Package for Social Sciences (SPSS, Version 23.0; IBM Corp., Armonk, NY, USA). The Shapiro-Wilk and Kolmogorov-Smirnov tests confirmed a parametric data distribution. Consequently, statistical analysis was conducted using independent t-test, and one-way repeated measures ANOVA. A p-value below 0.05 was deemed statistically significant.

RESULTS

[Table/Fig-3] illustrates the extent of canine retraction across different time intervals in the two groups. Analysis using one-way repeated measures ANOVA revealed a statistically significant variation in the extent of canine retraction over time between both groups ($p<0.05$). At 4 weeks, the test group demonstrated significantly greater tooth movement (2.5±0.3 mm) than the control group (1.5±0.2 mm) with $p=0.005$. This trend persisted for 8 weeks, with the test group showing a movement of 4.8±0.4 mm, exceeding the control group's 3.0±0.3 mm (p=0.003). By 12 weeks, the test group achieved a movement of 6.3±0.5 mm, again surpassing the control group's 4.0±0.4 mm (p=0.008). Extent of canine retraction was notably higher in group 1 (PBM and surgical corticotomy) at 4, 8, and 12 weeks [Table/Fig-4].

Time point	Baseline	4 weeks	8 weeks	12 weeks	F-value	p-value (Intragroup)[a]
Group 1- Test (mm)	1.3±0.4	2.5±0.3	4.8±0.4	6.3±0.5	245.6	0.0001*
Group 2- Control (mm)	1.1±0.1	1.5±0.2	3.0±0.3	4.0±0.4	182.4	0.0001*
t-value	2.51	11.071	19.64	18.17		
p-value (intergroup)[b]	0.015	0.005*	0.003*	0.008*		

[Table/Fig-3]: Comparison of extent of canine retraction between the groups.
*Statistically significant; [a]ANOVA; [b]Independent t test



[Table/Fig-4]: Line graph depicting the extent of canine retraction at baseline, 4, 8, and 12 weeks in test and control groups.

As shown in [Table/Fig-5], the independent t-test revealed a significantly higher rate of canine retraction in the test group compared to the control group. In the first month, the test group had significantly greater movement (2.50±0.30 mm) than the control group (1.50±0.20 mm). This continued in the second month, with the test group showing a higher rate (2.00±0.25 mm) than the control group (1.30±0.15 mm). In the third month, both groups experienced reduced movement, with the test group at 1.50±0.20 mm and the control group at 1.00±0.10 mm. By the fourth month, the test group further declined to 1.20±0.15 mm, while the control group had 0.90±0.12 mm. All comparisons showed statistical significance (p<0.05).

healing [20]. When combined, PBM optimizes the biological effects of corticotomy by enhancing the healing. This synergistic approach not only accelerates orthodontic tooth movement but also reduces treatment time, discomfort, and the risk of root resorption, making it a promising strategy for modern orthodontic care [21].

The present study aimed to evaluate the efficacy of combining PBM with surgical corticotomy to accelerate OTM. The results showed a marked increase in the extent of tooth movement in the test group, which received both PBM and corticotomy, compared to the control group that underwent corticotomy alone. These results align with prior research suggesting that PBM enhances bone remodeling and facilitates faster tooth movement by modulating cellular activity and stimulating tissue repair. Ekizer A et al., [22] explored the influence of light-emitting diode-mediated photobiomodulation therapy (LPT) on orthodontic Tooth Movement (TM) and root resorption in Wistar rats. The LPT group, treated with 20 mW/cm² energy for 10 days, showed significantly greater TM compared to controls (p=0.017). Root resorption was notably lower in the LPT group (0.098±0.066) than in controls (0.494±0.224, p<0.001). The findings suggested that LPT accelerates TM while reducing root resorption, making it a promising adjunct in orthodontic treatment.

Impellizzeri A et al., [23] evaluated PBM therapy for accelerating OTM in patients with ectopic canines. Eight canines were analysed, with four receiving PBMT. After one month, the PBMT group showed significantly greater displacement (1.98 mm) than controls (1.35 mm, p<0.05). Similarly, another clinical study demonstrated the magnitude of canine displacement after 1 month, which was 0.91 for the corticotomy group and 1.1 for the group which received PBM and corticotomy [24]. Ali FA et al., [25] assessed the effectiveness of erbium laser-assisted corticotomy in enhancing canine movement and found that, six weeks post-procedure, the canine movement on the laser-treated side was notably greater compared to the control side. Similar findings were reported by Mahmoudzadeh M et al., [26] who demonstrated that laser-assisted corticotomy significantly accelerated canine retraction. The present study findings are consistent with previous studies, as the test group demonstrated notably greater tooth movement compared to the control group at 4, 8 and 12 weeks. These findings suggest the synergistic effect of PBM and corticotomy, which underscore the cumulative effect of PBM over time, likely due to its ongoing stimulation of cellular processes associated with bone remodeling.

Furthermore, the present study documented that the rate of canine retraction between each time frame was statistically significant in favour of the test group. In a split-mouth clinical trial, Jaber ST et al., [27] evaluated the impact of erbium laser-assisted corticotomy on

Time interval	Group 1 (Mean±SD)	Group 2 (Mean±SD)	Mean difference (95% CI)	t-value	p-value (Intergroup)[a]
First month	2.50±0.30	1.50±0.20	1.00 (0.80-1.20)	10.74	<0.05*
Second month	2.00±0.25	1.30±0.15	0.70 (0.50-0.90)	9.30	<0.05*
Third month	1.50±0.20	1.00±0.10	0.50 (0.30-0.70)	8.66	<0.05*
Fourth month	1.20±0.15	0.90±0.12	0.30 (0.10-0.50)	6.05	<0.05*

[Table/Fig-5]: Comparison of rate of canine retraction between the groups.
*Statistically significant; [a]Independent t test

DISCUSSION

PBM and surgical corticotomy are techniques used to accelerate orthodontic tooth movement, each working through distinct mechanisms. PBM involves low-level laser therapy to stimulate cellular processes, particularly enhancing mitochondrial activity, which increases adenosine triphosphate production and accelerates bone remodeling by promoting osteoclast activation and osteoblast differentiation. This reduces the time required for bone resorption and deposition, thereby speeding up tooth movement [19]. In contrast, surgical corticotomy creates small cuts in the cortical bone, triggering a RAP that enhances bone turnover, circulation, and local

the speed of canine retraction over a 12-week period. They found that the canine retraction speed was significantly faster on the laser-treated side compared to the control side at 1, 2, and 3 months, with the highest retraction observed at the end of the first month. Similarly, Alfawal AM et al., [28] who also utilised the erbium laser, reported that the rate of canine retraction on the test side during the first month was nearly double that of the control side. The present study results are in accordance with previous findings, as the peak rate of retraction was observed at the end of first month, which declined over time. However, the retraction rate was considerably greater in the test group compared to the control group.

The application of PBM therapy in this study was found to be both effective and minimally invasive. The choice of a split-mouth design ensured that each patient served as their own control, minimizing variability due to individual differences in bone density, healing capacity, and other factors. Moreover, the use of standardized orthodontic forces and consistent follow-up schedules further strengthened the reliability of the results.

Limitation(s)

Although the combination of PBM and corticotomy showed promising results in terms of extent and rate of canine retraction, some limitations need to be considered. The study primarily focused on the extent and rate of tooth movement, other clinically relevant outcomes, such as long-term stability, root resorption, and patient satisfaction, were not assessed. Future research examining additional clinical outcomes is necessary to confirm these results and assess their relevance to orthodontic treatment.

CONCLUSION(S)

In conclusion, the integration of PBM with surgical corticotomy significantly accelerates the rate of OTM compared to corticotomy alone. The synergistic effect of these techniques holds promise for revolutionising orthodontic practices, offering both clinicians and patients a less invasive yet highly effective strategy for achieving rapid and efficient tooth movement. Further research should explore the long-term effects and optimal protocols for combining these modalities.

Authors' contribution: ARP: Conceptualisation, methodology, software, data curation, and writing – original draft preparation. AR: Visualisation, investigation, supervision, validation, and writing - reviewing and editing.

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