Original Article

The Innovated Laser Assisted Flapless Corticotomy to Enhance Orthodontic Tooth Movement

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Abstract:

Introduction: Corticotomy-facilitated orthodontics provides a means for rapidly moving teeth purportedly with little damaging effects to the periodontium and with greatly reduced treatment time. The aim of this study was to enhance the orthodontic tooth movement by reducing the cortical bone layer (resistant to bone re-sorption relative to spongious bone) following Erbium, Chromium doped Yttrium Scandium Gallium Garnet (Er-Cr: YSGG)laser irradiation, without reflection of surgical soft tissue flap.
Methods: In the present experimental study, 8 New Zealand Male rabbits were the samples for the research. The right first premolar of each rabbit (experiment group) underwent treatment for mesial movement with 75 gram of orthodontic force by using closed Ni-Ti coil spring (Dentaurum®). Coil spring was fixed in the cervical region of first premolars by means of ligature wire and No-Mix composite (Dentaurum®) and also activated to the cervical site of incisors. The left first premolars of the subjects were considered as the control group. Laser corticotomy was performed in anesthetized rabbits. Samples were sacrificed for determination of tooth movement after initiating premolar protraction on the 21^{th} day. The amount of orthodontic tooth movement was assessed by using a metal feeler gauge with the precision of 0.01 mm, between mesial surface of the second premolars and distal surfaces of the first premolars. The statistical package of SPSS (Kolmogorov - Smirnov and ANOVA test) was used for analytical evaluation of the measurements.
Results: The amount of orthodontic tooth movement in the experimental group (mean=1.653±0.34 mm) was significantly ($p<0.001$) greater than that of the control group (mean=0.936 ±0.28 mm). The innovated laser assisted corticotomies enhanced the rate of orthodontic tooth movement on the intervention side, significantly ($p<0.001$).
Conclusion: The innovated method of laser assisted flapless corticotomy is a useful procedure for reducing treatment time and damage to periodontium. It also eliminates the necessity of more invasive intervention of flap surgery.
Keywords: movement, tooth;orthodontic; laser.

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Introduction

The average length of orthodontic treatment is two years depending on the treatment options and individual characteristics. To increase efficiency, orthodontists have tried various approaches to decrease treatment time. Corticotomies have recently become popularized, which uses bone healing mechanisms in combination with orthodontic loadings to decrease treatment times (1). Corticotomy-facilitated orthodontic treatment may be considered as intermediate therapy between orthodontic surgery and conventional orthodontics for reducing treatment time (2). Dental distraction has been presented as a technique whereby the mesial aspect of the socket of an extracted first premolar tooth was directly modified (surgically undermined) in such a way as to allow "distal distraction" of the adjacent cuspid. The alveolus or the periodontal ligament (PDL), or both, were forcibly distracted into a new configuration. Authors claimed no adverse effects to the periodontal support and the PDL re-established integrity after averaging 6.5 millimeters of cuspid retraction in 3 weeks (3).

An orthodontic master's thesis by Hajji was conducted to determine the differences among conventional non-extraction, conventional extraction and the accelerated osteogenic orthodontics techniques on lower dental arch de-crowding. It was discovered that duration of the mentioned therapy was 3 times less than the conventional non-extraction therapy (4). In 1959, Kole innovated the corticotomy procedure. He hypothesized that by reducing the resistant cortical bone through surgical procedure, the tooth will be able to be moved more rapidly (5). Distinguished orthopedist, Harold Frost, observed a direct correlation between the degree of injury response with the intensity of physiological healing response, which he coined Regional Accelerated Phenomena (RAP). RAP does not provide new healing processes, but rather explains the acceleration of normal healing events; the greater the insult, the more accelerated and intense the regional healing response (1). Wilcko has demonstrated rapid orthodontic tooth movement following selective labial and lingual decortication of alveolar bone in the area of desired tooth movement using a patented/trademarked technique called Accelerated Osteogenic Orthodontics (AOO). Dental arch crowding is routinely resolved and the finishing stage is completed in 4-6 months of active orthodontic treatment following the corticotomy surgery and alveolar grafting (6).

On the other hand, the use of lasers for therapy has become very common in medical field (7-9). In view of the recent advances and the development of different delivery systems with a wide range of laser wavelengths, researchers postulated that lasers could be applied for dental treatment (10-11). Lasers, in general, consist of an active medium and a pumping source enclosed in an optical cavity. The pumping source pumps the active medium from its ground state (inactive state) to an excited state. Very intense flashes of lights or electrical discharges pumps the lasing medium and creates a large collection of atoms in excited state for the laser to work efficiently. Based on the active lasing medium, it can be a container of gas or a solid crystal rod. The gas-active medium lasers available in dentistry today are argon and Carbon Dioxide Laser (CO_2) lasers. In solid-state lasers, a garnet crystal made from yttrium and aluminum is commonly used and these are known as Yttrium Aluminium Garnet (YAG) lasers (12).

The advantages of laser application can be summarized in creating a clear, dry field with no bleeding, decreasing the possibility of infection, creating less trauma to the area, post-operative swelling and scaring along with minimal post–operative pain (13). Various reports have confirmed the safety and efficacy of CO_2 and Neodymium-Doped Yttrium Aluminium Garnet

(Nd; YAG) lasers, which are the most common used lasers in soft tissue application (14-17).

Hibst et al were the first to report the use of the Erbium: Yttrium Aluminium Garnet(Er: YAG) laser in 1988 for ablation of dental hard tissues (18). During the same period, several researchers examined the effectiveness of this laser for hard tissue ablation (19-22). Among all the lasers, Er: YAG laser possesses characteristics suitable for oral treatment, due to its dual ability to ablate soft and hard tissues with minimal damage. Also, its bacterial effect with elimination of lipopolysaccharide, ability to easily remove plaque and calculus, irradiation effect limited to an ultra-thin layer of tissue, even or faster bone repair after irradiation than conventional bur drilling, and effective ability for implant maintenance, make it a promising tool for periodontal treatment (12). An Er: YAG laser may represent a suitable alternative for defect and root surface debridement in conjunction with periodontal surgery (23).

The application of the Er: YAG laser on bone in oral and periodontal surgery is not very common and there are few reports regarding the use of this laser for bone ablation (24-29). Nelson et al reported that the Er: YAG laser ablated bone effectively with minimal thermal damage to the adjacent tissues (26). The ability of bone tissue removal with minimal chemical and morphological changes to the irradiated and surrounding surfaces was demonstrated previously. A typical irregular pattern, which consisted of biological apatites surrounded by an organic matrix, was observed in the irradiated bone and this may have aided in uneventful healing (24). Lewandrowski et al reported that the healing rate following Er: YAG laser irradiation may be equivalent or even faster than the following bur drilling (27). Sasaki et al showed, histologically, a thin altered layer produced by Er; YAG laser on the irradiated rat calvaria bone surface. On the other hand, the bone ablated using CO_2 laser showed extensive thermal effects (24). In another study, Pourzandian et al demonstrated that the initial bone healing following Er: YAG laser irradiation occurred faster than that after mechanical bur drilling and CO_2 laser irradiation in rats, observed by light and transmission under electron microscopy (29).

However, to obtain the desired success of periodontal treatment without damage of the surrounding tissue, the appropriate laser parameters, such as power energy, energy density and time of irradiation have to be used (12). Even though successful experimental results have been reported so far with Er:YAG laser, future studies are required to better understand the effects on biological tissues for its safe and effective application during periodontal therapy.

Several studies have revealed that the healing process that takes place in the soft tissue and underlying bone following perforation by an Er,Cr:YSGG is favorable (30-32). The laser parameters such as power density, mode, pulse duration, and the correct proportion of water and air, are crucial to achieve optimum conditions in the ablation rate, thermal safety and desirable outcome.

The aim of this study was to enhance orthodontic tooth movement through innovated laser (Er,Cr:YSGG) assisted flapless corticotomy around first right mandibular premolar of rabbits.

Methods

In this experimental study, tooth movements of 8 New Zealand rabbits male were investigated. The first mandibular premolar of each rabbit was considered for mesial movement with 75 gram of orthodontic force, using closed Ni-Ti coil spring (Dentaurum ®). Coil springs were fixed in cervical region of first premolars by means of ligature wire and No-Mix composite (Dentaurum®) and also activated to cervical site of Incisors. Left first mandibular premolars of subjects were considered as control group and right premolars as experiment group. The rabbits were anaesthetized with an intramuscular injection of Ketamine hydrochloride (50mg/kg) and Xylazine (10mg/Kg). The Er,Cr;YSGG laser device (Waterlase, Biolase, USA) was used to deliver an energy range about 300 mJ at pulse rates of 20 Hz. The laser ablation or bone cutting was performed under water-spray cooling to improve the absorption of laser radiation by the bone, and thus to prevent thermal interactions like carbonization in the region adjacent to the laser-cut. Duration of laser irradiation for each penetration was between 0.25-0.5 second and it was in a noncontact manner with a 2 mm distance. The proportion of air and water was 40% and 20% respectively.

Samples were sacrificed with an overdose of sodium pentobarbital on the 21^{th} day. The amount of orthodontic tooth movement was assessed by using a metal feeler gauge with the precision of 0.01 mm, between mesial surfaces of the second premolars and distal surfaces of the first premolars. The data were recorded and subjected to ANOVA and kolmogorov-Smirnov tests for statistical analysis.

Results

None of the rabbits showed clinical signs of swelling or displayed healing problems of the periodontal tissues beyond 10 days post-surgery. Within 2 weeks of operation, the tissues on the side with the corticotomy procedures appeared similar to the side without corticotomies. The rate of orthodontic tooth movement in the experimental group (mean=1.653±0.34 mm) was significantly ($p<0.001$) greater than that in the control group (mean=0.936 ±0.28 mm). Data showed that laser assisted flapless corticotomy can enhance orthodontic tooth movement without jeopardizing the healing process of the soft tissue and the hard tissue.

Discussion

Orthodontic forces with the laser-assisted corticotomy procedures produced substantially greater mandibular tooth movements than orthodontic forces alone. Our findings about the differences between the control and the experimental sides support the findings of Iino et al (33) and Cho et al (34), who also found approximately twice as much tooth movement in beagle dogs. However, they reported greater absolute amounts of tooth movement, which could have been due to the animal model used. Our findings are consistent with the A. Sanjideh et al's (35) research which represents a significant greater amount of tooth movement in the corticotomy sides than the control ones. The corticotomies may have produced greater amount of tooth movements as it increased bone turnover (36-38).

Orthodontic tooth movements might be expected to stimulate accelerated bone remodeling. As shown experimentally by Deguchi et al (39), bone turnover rates are significantly greater on the side that underwent orthodontic forces than on the control side. Thus, orthodontic tooth movements might be expected to have influenced the results of the present study, but these effects were controlled because both sides of the mouth were similarly treated.

By day 21, the corticotomy side showed approximately twice as much tooth movement compared with the control side. Iino et al (33) and Cho et al (34) also found approximately twice as much tooth movement after 1 week on the corticotomy side versus the control side. It has also been suggested that greater amounts of noxious stimulus produce a greater RAP (Regional Acceleratory Phenomenon) effect (40,41) which could explain the tooth movement differences between the experimental and the control sides.

The rate of tooth movement peaked at day 21 on the corticotomy side which is similar to previous studies that showed tooth velocities peak between the first (33) and the third (34) week after corticotomies were performed. Peak tooth velocities represent a transition from the catabolic to the anabolic phase of RAP, while bone density is least and tooth movements might be expected to be greatest.

In rats, osteoid begins to mineralize after about 20–55 days (42). According to those authors, anabolic modeling of alveolar trabecular bone adjacent to decortication increases 150 per cent by 3 weeks. Since the anabolic levels of RAP increase through time, it is reasonable to expect that tooth movement would slow as bone density increased.

In one study, Youssef M. et al (43) evaluated the effect of a low –level laser on orthodontic tooth movement and suggested that the velocity of canine movement was significantly greater in the lased group than in the control group. Seifi M. et al (44) in another study evaluated the effect of 2 models of low-level lasers on the movement of mandibular first molars in rabbits and concluded that there were statistically significant differences between the control and the two other laser-irradiated groups. The findings implied that the amounts of orthodontic tooth movement, after low-level laser therapies were diminished.

Other methods of initiating the RAP, such as corticision (45) or electrical stimulation (46) may provide a less invasive and a more cost-effective alternative, but all of these possibilities require further investigation.

Although corticotomies obviously increased the rates of tooth movement, significant reductions in treatment time of comprehensive orthodontic cases remain questionable. Case reports have shown that comprehensive orthodontic treatment can be completed in 4–9 months with corticotomies (1,6,47), whereas conventional orthodontics takes 18 – 30 months (48). Based on the previous longitudinal experimental evidence (33,34), tooth movement rates approach control values after approximately 3 – 7 weeks. So, it is difficult to understand how a single corticotomy can accelerate the treatment time by 14-21 months. Even though dogs heal only slightly faster than humans (49), it is possible that the RAP effect is different in humans than in dogs. The thicker cortical bone of dogs could also be responsible for some of the differences. Since the greatest tooth movement during orthodontic treatment happens during aligning and leveling phases, which typically takes about 6 months (50,51), corticotomies might be best indicated for this treatment phase. Moreover, controlled randomized trials are required to ascertain the true efficacy and most appropriate time to perform corticotomies.

Case reports show little or no loss of gingival attachment associated with corticotomy (5,6,47). While no adverse effects have been noted in the soft tissues in this study, well controlled trials have not been performed to establish the health of the periodontal tissues after corticotomy. Histological data must also be evaluated to determine the mechanisms related to accelerated tooth movement.

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