STM JOURNALS

Research & Reviews: A Journal of
Dentistry

http://medicaljournals.stmjournals.in/index.php/RRJoD/index

ISSN: 2230-8008 (Online)
ISSN: 2348-9561 (Print)
Volume 15, Issue 1, 2024
January—April
DOI (Journal): 10.37591/RRJoD

Review RRJoD

Repeated Micro-osteoperforations Versus Dual Approach in Accelerated Orthodontics

Akhil Anton Joy[1,*], Pradeep Raghav[2], Amit Kumar Khera[3],
Neha Jairath[1], Alisha Bansal[1], Shivika Garg[1]

Abstract

In contemporary orthodontics, there is a pressing need to minimize treatment duration, which concerns both orthodontic specialists and patients. Prolonged treatment periods not only pose logistical challenges but also increase the risks of various dental issues such as cavities, periodontal problems, chronic discomfort, and root resorption. Accelerated orthodontics has emerged as a promising solution to address these challenges. Numerous efforts have been undertaken to expedite orthodontic tooth movement (OTM) through innovative approaches, encompassing both invasive surgical techniques and non-invasive methods involving pharmacological and physical stimulation, alongside traditional orthodontic mechanics. Surgical interventions, notably corticotomy and piezoelectric ultrasonic bone punctures, stand out as prominent methods for stimulating the rate of OTM. These approaches capitalize on the concept that inducing controlled injury to the bone through surgery triggers an inflammatory response, leading to accelerated osteoclastogenesis and consequently facilitating faster tooth movement, a phenomenon known as the Regional Acceleratory Phenomenon (RAP). However, due to the invasive nature of corticotomy and other surgical techniques, patient compliance is in doubt because of the possibility of adverse effects such as pain, bleeding after surgery, and a decline in patient quality. As a result, a number of minimally invasive techniques that accomplish the same goals as traditional corticotomy but with less invasiveness and morbidity have been developed. These techniques include piezosurgery, fiberotomy, micro-osteoperforations (MOPs), and so forth. It has been demonstrated that non-invasive methods, along with mechanical or physical stimulation of the periodontal ligament, can hasten bone remodeling. Numerous techniques have been attempted to achieve this goal; lasers and vibrations are very effective. The ease of use and versatility of lasers have led orthodontists to use them in a variety of applications. Soft laser therapy or Low-Level Energy Laser Therapy (LLLT) is the type of laser used in the field of orthodontics. The biostimulatory action of LLLT has a variety of indications, including the acceleration of OTM, retention procedures, and pain relief. While MOPs and LLLT have shown successful results when used separately for accelerating OTM, the synergistic effects of MOPs along with LLLT are less discussed. This review briefly portrays MOPs, LLLT, and the effects of their combined application in accelerating OTM.

Keywords: Orthodontic tooth movement, micro osteoperforations, orthodontics, corticotomy, piezoelectric ultrasonic bone punctures

***Author for Correspondence**
Akhil Anton Joy
E-mail: akhilantonjoy@gmail.com

[1]Student, Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College and Hospital, Meerut, Uttar Pradesh, India
[2]Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College and Hospital, Meerut, Uttar Pradesh, India
[3]Professor, Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College and Hospital, Meerut, Uttar Pradesh, India

Received Date: February 26, 2024
Accepted Date: February 27, 2024
Published Date: March 15, 2024

Citation: Akhil Anton Joy, Pradeep Raghav, Amit Kumar Khera, Neha Jairath, Alisha Bansal, Shivika Garg. Repeated Micro-osteoperforations Versus Dual Approach in Accelerated Orthodontics. Research & Reviews: A Journal of Dentistry. 2024; 15(1): 16–21p.

INTRODUCTION

Reducing treatment duration is one of the most challenging tasks in orthodontics in recent times. Both the orthodontic specialist and the patient express worry regarding the length of the treatment. Though challenging, many attempts have been made to reduce the orthodontic treatment period by accelerated orthodontics. Higher treatment duration has been also linked to an increased risk of cavities, periodontal issues, chronic discomfort, and root resorption [1]. So accelerated orthodontics has good scope in modern orthodontic practice. Plenty of attempts have been made in recent years to expedite orthodontic tooth movement (OTM) using invasive surgical techniques and non-invasive techniques which include both pharmacological and physical stimulation techniques, in addition to traditional orthodontic mechanics [2].

Surgical approaches for stimulating the rate of OTM are mainly corticotomy and piezoelectric ultrasonic bone punctures. Surgical options have long been utilised to accelerate tooth movement. These procedures were developed on the idea that when the bone is surgically injured, an inflammation cascade is triggered, resulting in enhanced osteoclastogenesis and, as a result, faster tooth movement (regional acceleratory phenomenon or RAP) [3]. Since corticotomy and other surgical methods are invasive procedures that might result in some side effects such as postoperative bleeding, pain, and a negative impact on patients' quality of life, and because of these side effects patient compliance is a question mark [4]. As a result, various minimally invasive methods, such as piezosurgery, fiberotomy, micro osteoperforations (MOPs), and so on, have emerged that achieve the same objectives as conventional corticotomy but with less invasiveness and morbidity [5]. Several investigations on both animal models (rats) and human clinical trials performing MOPs revealed that MOP dramatically boosted molar protraction with additionally enhancing osteoclastogenesis, inflammatory cytokine production, and alveolar bone remodelling [6].

Non-invasive techniques include injections of prostaglandin E and vitamin D, electric and magnetic stimulation, pharmacological injections of parathyroid hormone, misoprostol (prostaglandin E1 analogue), relaxin, also low-energy laser, and vibrating toothbrushes [7]. Mechanical or physical stimulation of the periodontal ligament has been proven to accelerate bone remodelling. Many methods have been tried for this aim, with lasers and vibrations yielding excellent results.

After Maiman developed the first LASER in 1960, dental interest in lasers has been considerably increased, and studies into ways to improve dental therapy with lasers are ongoing [8]. The ease of use and versatility of lasers has led orthodontists to use them in a variety of applications, including diagnostic procedures, the prevention of white spot lesions, bracket debonding, and minor surgical operations such as gingivectomy and frenectomy. Soft laser therapy or Low-Level Energy Laser Therapy (LLLT) is the type of laser that is used in the field of orthodontics, it is also known as cold laser therapy. The discovery of LLLT's biostimulatory action in 1967 cleared the path for its usage in a variety of indications, including in the acceleration of OTM, retention procedures, and pain relief [9, 10].

Since MOPs and LLLT when used separately for accelerating OTM and have found successful results. But the synergistic effects of MOPs along with LLLT are least discussed. It was useful to compare the benefits of repeated MOPs to the combination strategy of MOPs and LLLT in speeding OTM.

ACCELERATED ORTHODONTICS

In our increasingly informed and sensitive culture, there is a growing demand for orthodontic care. Both adults and children pursue orthodontic care to enhance their social and psychological welfare. Along with technological advancements, comes a rise in the desire for faster and more efficient orthodontic treatment.

Extended durations of treatment also elevate the likelihood of experiencing caries, periodontal disease, and root resorption. As a result, the prospect of accelerating the biological response of the periodontal ligament and alveolar remodelling is appealing, as it may allow for faster tooth movement and shorter treatment time [11].

Efforts to speed tooth movement can be traced back to the 1890s, practically contemporaneously with Angle's pioneering work in modern orthodontics. OTM occurs through the application of physical forces, which then prompt the restructuring of the alveolar bone and periodontal ligament (PDL). Bone remodeling is a coordinated process comprising both bone resorption (at the site under pressure) and bone formation (on the tension site). The amount of OTM is determined by the amount of applied force and the PDL's biological responses. The orthodontic force applied to the tooth will result in changes in the micro-environment surrounding the PDL fibres resulting in the release of multiple mediators of inflammation including growth factors, colony-stimulating factors cytokines, neurotransmitters, and arachidonic acid metabolites, etc., thus results in bone remodelling.

Multiple drugs have been used successfully to increase OTM for a long time. Vitamin D, prostaglandins, interleukins, parathyroid hormone, misoprostol, etc. are a few examples. However, all of these medications have some sort of unfavorable side effects [12].

For a long time, surgical techniques have been utilised to speed up tooth movement. These methodologies were developed on the concept that surgical irritation of the bone initiates an inflammatory cascade, leading to increased osteoclastogenesis and consequently accelerating tooth movement—referred to as either the RAP or Periodontally Accelerated Osteogenic techniques Orthodontics (PAOO). RAP is defined by Frost as a complicated reaction of mammalian tissues to many unpleasant stimuli. Any sufficiently unpleasant localised stimulation in a normal body appears to elicit a RAP.

The extent of the impacted area and the level of its reaction seem to fluctuate. The size of the affected area and the strength of its response seem to correlate directly with the intensity of the stimulus, albeit with differing degrees among individuals. Many ongoing regional soft and hard tissue essential processes accelerate above normal ranges when provoked. These accelerated processes are referred to together as the RAP. Since these surgical methods have the least patient compliance, newer minimally invasive methods have emerged which can achieve the same orthodontic effects as traditional coticotomies such as piezosurgery, fiberotomy, and MOPs.

Mechanical or physical stimulation of the PDL has shown an increase in the speed of bone remodelling. Among the available methods, lasers and vibration appear to hold the most promising position. They have been demonstrated to be effective by promoting osteoclastogenesis via the RANK/RANKL pathway and signaling molecules such as Mitogen-Activated Protein Kinase (MAPK), c-Fos, and nitric oxide. These techniques have also been found to minimise orthodontic relapse, discomfort, pain, and root resorption [13, 14].

MICRO-OSTEOPERFORATIONS (MOPs)

MOPs is an orthodontic procedure involving the creation of tiny perforations around the teeth's bone to expedite the pace of tooth adjustment during orthodontic therapy. The MOPs technique may be conducted by the orthodontist as determined by clinical demands, with minimum discomfort or problems to the patients. This process causes the release of cytokines, which attract osteoclasts to the region, increasing the rate of bone resorption. Orthodontics has introduced a device called Propel for conducting MOPs, which reduces the invasiveness associated with surgically irritating the bone.

Effect of Repeated MOPs on OTM

As of now, limited and conflicting literature evidence based on MOPs are available, with early data generated from models of animals and few clinical studies among humans showing contradictory findings. Further research is required to gain a deeper understanding of the therapeutic applications of MOP in orthodontics.

The MOP procedure has already proven effective in animals as well as humans. MOP causes a rise in inflammatory marker levels, which leads to enhanced osteoclastic activity and tooth movement velocity. When utilizing the Propel device (Ossining, NY) for MOP, the rate of canine retraction saw a 2.3-fold increase in comparison to the control group. Patients noted only slight discomfort at the MOP sites [15].

Venkatachalapathy and colleagues found that when MOPs were repeated every 28th day for 84 days, the rate of canine retraction spiked two-fold relative to the control side. When MOP was repeated three times, the maxillary canine demonstrated substantially faster tooth movement than the mandibular canine. They concluded that the orthodontic treatment period can be cut down by 62% using MOPs. As a result, MOPs can be used in routine orthodontic mechanics and at various phases of treatment to aid in alignment and root movement, stimulate bone remodelling in areas of inadequate alveolar bone structure, and reduce stress on anchor units [16].

Alikhani et al. revealed that MOP using mini-screws speeds up retraction by nearly 1.5 times [6]. The MOP approach was supposed to promote tooth mobility by promoting faster bone remodelling, as well as increasing osteoclast number and new bone production on MOP sides.

Using cone-beam computed tomography images, Asif et al. evaluated the impact of MOPs on mandibular bone volume/tissue volume (BV/TV) ratio alterations and the rate of OTM. It was suggested that the MOP approach if regularly repeated during orthodontic therapy, can enhance the rate of OTM [17].

Cheung et al. reported that MOPs enabled by mini-screws could successfully increase the rate of tooth movement in rats. It has been demonstrated that increasing the total count of perforations increases the level of cytokines and osteoclastogenesis, that can speed up tooth movement. As a result, clinicians should choose the number of MOPs on an individual basis rather than limiting themselves to three [18].

PHYSICAL/MECHANICAL STIMULATION METHODS

Surgical techniques, regardless of method, are nonetheless invasive to some extent and, as a result, have problems. As a result, non-invasive approaches have gained popularity. Lasers, vibration, direct electric current, and other modalities are few examples of these techniques.

Lasers

The term "Laser" originates from "Light Amplification by Stimulated Emission of Radiation" and has a history of approximately 50 years. The inaugural functional laser was developed in 1960 at Hughes Research Laboratories by the American physicist, Maiman. This laser utilized a synthetic ruby crystal composed of aluminum oxide and chromium oxi3.

Effects of LLLT in OTM

Lasers have a variety of applications in orthodontics. That includes acceleration of OTM, bone remodelling, etching of enamel before the bonding procedure, debonding of ceramic brackets, reduction of pain after orthodontic treatment, and avoidance of enamel demineralization. Various soft tissue applications of dental lasers are frenectomies, gingivoplasties, and crown lengthening [19].

LLLT often known as photobiomodulation is one of the most promising treatments today. Laser has been found to have a biostimulatory impact on bone regeneration in the mid-palatal suture during rapid palatal expansion, and it also stimulates bone regeneration following bone fractures and extraction sites. Laser light has been shown to enhance the growth of osteoblasts, osteoclasts, and fibroblasts, affecting bone remodelling and accelerating tooth movement. The synthesis of ATP and activation of cytochrome C is the idea behind the acceleration of OTM, as illustrated by the fact that low-level therapy boosted the rate of OTM via RANK/RANKL and the macrophage colony-stimulating factor and the expression of its receptor.

Experiments on animals have demonstrated that a low-level laser can speed tooth movement. In addition, research attempts were done with varied laser intensities and diverse results have been obtained. According to Kawasaki and Shimizu, LLLT can be a greatly beneficial technique for accelerating tooth movement since it improves bone remodelling without causing periodontal adverse effects. In experiments with rats, a laser wavelength of 800 nm and output power of 0.25 mW resulted in considerable stimulation of bone metabolism, fast ossification, and a 1.5-fold acceleration of OTM [20]. Recently, in a clinical trial investigation, the laser wavelength employed in a continuous wave mode at 800 nm, with an output of 0.25 mW and exposure time of 10 sec, was found to speed up tooth movement of about 1.3-fold faster than the control group. In another experiment conducted by Kau on 90 subjects (73 participants in the experiment and 17 controls), the test subjects had a 1.12-mm change each week as compared to 0.49 mm in the control group.

Effect of Dual Approach in Accelerated Orthodontics

MOPs and LLLT have both demonstrated consistent effects in speeding OTM. However, the synergistic effect of MOPs and LLLT was barely mentioned. Abdelhameed and Refai stated that Direct intra-oral measurements of the rate of OTM with MOPs were roughly 1.6-fold higher in three months than with traditional orthodontic therapy [21]. MOPs were repeatedly done every two weeks for three months (six times). In three months, direct intra-oral measurements and statistical analysis of LLLT revealed that the velocity of OTM with the LLLT side was about 1.3-fold higher than traditional orthodontic therapy. The potential of LLLT to speed up canine retraction can be demonstrated through its effect on the nuclear factor KB (RANK)/RANKL/osteoprotegerin (OPG) pathway, which is required for osteoclastogenesis in both animals and humans. Furthermore, direct intra-oral measurements statistical analysis from samples in which both MOPs and LLLT were employed jointly revealed that the rate of OTM in the combined MOPs & LLLT side was about 1.8-fold greater in three months as compared to regular orthodontic therapy. The increased rate of OTM in the combined MOPs & LLLT strategy may account for the synergistic impact observed when the two procedures were combined [21].

CONCLUSION

Both repeated MOPs and LLLT when used separately have provided positive effects in accelerating OTM. But the synergistic effect of combined repeated MOPs and LLLT have been less researched upon and hence less discussed. Studies have shown that the rate of OTM increased when MOP was repeated three or more times.

Numerous studies have demonstrated that both MOPs and LLLT techniques, when utilized independently, effectively expedite the rate of canine retraction in orthodontic treatment. Specifically, the MOPs technique has shown to accelerate the rate of canine retraction more significantly as compared to applying LLLT, in contrast to the standard method for canine retraction. But the combination of MOPs and LLLT has very few scientific evidence to prove that there is a statistically significant effect in accelerating OTM.

Till now only fewer studies have been conducted on the topic, hence the exact outcome of the effect of repeated MOPs versus dual approach in accelerated orthodontics can be obtained only with the help of future research and studies.

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