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Accelerated orthodontic treatment - what's the evidence?

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ABSTRACT

The demand and accessibility of orthodontic care has increased but has also been accompanied by patient requests for shorter treatment times. Longer orthodontic treatment increases the risk of decalcification, gingival recession, and root resorption and so shorter treatment times have multiple advantages as well as appealing to patient's desires. Numerous techniques and materials have been suggested to reduce treatment times but, in most cases, are based upon selected case reports with no prospective clinical trials to validate claims. The present review examines many of the current options purported to accelerate orthodontic tooth movement and the level of evidence presently available. There is some evidence to suggest that low-level laser therapy and a corticotomy involving the raising of a muco-periosteal flap are associated with accelerated orthodontic tooth movement; however, the current level of evidence is low to moderate in quality. For this reason, further research is required before routine application could be recommended.

Keywords: Accelerated tooth movement, corticotomy, Orthodontics, vibration.

Abbreviations and acronyms: SL = Self-ligating; PRP = platelet rich plasma; PDGF = platelet derived growth factor; TGF = transforming growth factor; RANKL = Receptor Activator of Nuclear Factor Kappa B Ligand; PBM = Photobiomodulation; MOP = Micro-osteoperforations; PAOO = periodontally- accelerated osteogenic orthodontics.

INTRODUCTION

Comprehensive orthodontic treatment times vary widely but the current best evidence based on prospective studies performed in university settings indicates that comprehensive treatment requires, on average, less than 2 years to complete.[1] Several factors can play a role in the length of treatment and include case severity, an extraction or non-extraction approach, clinical expertise, and patient cooperation.[2] For example, research has indicated that the correction of Class II relationships takes approximately five months longer than Class I occlusions[3] with the severity of the overjet explaining 46% of the variability in treatment duration.[4]

Along with longer treatment times, comes an elevated risk of root resorption and decalcification. However, because patients want significantly shorter treatments of only 6-12 months,[5] there is a significant incentive for orthodontic providers and companies to find ways to accelerate treatment. Several orthodontic companies now offer brackets, techniques and other appliances that claim to reduce treatment times. There has also been a dramatic increase in the number of orthodontic courses for general dental practitioners offering faster treatments and an increasing number of products claiming to accelerate tooth movement.

Possible interventions can be categorised as surgical or non-surgical.[6] In turn, the interventions may have an influence on two basic aspects of orthodontic tooth movement; firstly, the physics of force application (orthodontic mechanics) and secondly, the biological response of the dentoalveolar tissues to this force. The purpose of this paper is to review the evidence regarding the current available methods and examine the mechanical and biological plausibility of the proposed options.

NON-SURGICAL METHODS

Limited Orthodontic Treatment

These are the quick/fast/rapid/express treatments marketed to the general dental practitioner and performed by orthodontists when limited treatment is indicated or selected by a patient after informed consent and a discussion of all possible options. The marketing related to product name selection is chosen to be appealing as the adjectives used imply a greater velocity of movement. If terms such as 'incomplete' or 'limited' were used they would obviously have less desirability and yet are, in most cases, a more accurate descriptor.

Limited orthodontics is a form of treatment which involves a shortened period of time of up to 6

months, and usually is restricted to the use of round wires which can improve rotations and vertical discrepancies. In comprehensive orthodontic treatment, this is a component of the first phase of treatment often termed 'levelling and alignment'. The more obvious rotations and tipping movements occur relatively quickly but this is the point at which limited orthodontic treatment ceases. For some cases, this may be a suitable treatment outcome to fulfil a patient's treatment needs. However, the slower and more difficult phases of treatment then commence which include the torqueing of roots within the alveolus, the antero-posterior correction, transverse coordination and the control of vertical discrepancies. In addition, the detailed finishing of the alignment and occlusion is not performed and, for most patients, this is important to achieve their desired treatment goals.

The appliances used for limited orthodontic treatment are conventional brackets and arch wires and so there is no evidence or mechanical justification to support any claims that these are faster treatments. They are simply limited treatments set to achieve specific goals rather than a comprehensive solution. Therefore, an important issue is that both limited and comprehensive treatment options are explained to the patient so they are aware of the risks and limitations and are able to make an informed choice about the most appropriate approach to reach their goals.

Self-ligating and varying bracket designs

Self-ligating (SL) brackets have been in clinical use almost as long as the conventional edgewise bracket as designs appeared in the 1930's. The designs included what would now be called 'passive' and 'active' brackets of a similar appearance to contemporary designs. Self-ligating brackets were initially designed to save time during an era when arch wires were tied into brackets with steel ligatures. Over the last 20 years, SL brackets have undergone a re-emergence with more user-friendly appliance designs. However, along with this has been a change in marketing focus on the potential reduced friction provided by a SL bracket compared with elastomeric module ligation. The claim has been made that, along with low friction in the laboratory, comes more rapid alignment and a reduction in treatment time in the clinical setting. These claims appeal to the desires of both orthodontists and patients. The first retrospective clinical studies on treatment efficiency in 2001 supported the finding of shorter treatment times.[7,8] The studies were retrospective in design with the inherent flaws and risks of bias. Retrospective studies by their very nature have sources of bias as subjects were chosen for a particular intervention (selection bias) whereas in a prospective RCT the subjects have an equal chance of being distributed to the various treatment (or no treatment/control) options. The potential impact of known confounders can be controlled, to some extent, in retrospective studies by matching and multivariable analysis. However, potential unknown confounders are not controlled and could influence the study outcome. There can also be recall bias in that only certain subjects return and this could be biased toward the success or failures. Finally, even if a retrospective study's statistics establish a correlation, causation cannot be established as an association may be indicated but this does not mean that the parameters in question have a direct or causal relationship.

The first prospective clinical trials did not appear until 4-5 years later and found no difference in treatment effect.[9,10] Subsequently, there have been numerous well-designed randomised clinical trials from which the generated information has been combined into the highest levels of evidence of systematic reviews and a meta-analysis. Two systematic reviews concluded that there was no difference between conventional brackets and SL brackets in treatment time or the number of visits required.[11,12] A more recent meta-analysis combined the data from several studies and concluded that no clinical recommendation can be made regarding the different ligation modes.[13] No conclusive benefits could be proven for SL brackets, while their use was associated with a longer treatment duration by an average 2 months. Similarly, various bracket designs have appeared which claim or imply faster marketed treatment. These designs, including many SL brackets, are often narrower than conventional brackets and are promoted to apply less force with lower friction. This is not a new principal and, in fact, the Begg Light-Wire system was probably the ultimate low force/light wire appliance which relinquishes control in the early stages of treatment to allow more tipping and uncontrolled movement which takes substantially longer to regain. Brackets transitioning from the Begg system were designed to improve control but still allowed more tipping and arch wire deflection but were found to be less efficient in space closure due to more time spent in uprighting the root apices later in treatment.[14] All narrower brackets including triangular designs suffer from this mechanical weakness. The current evidence does not support the use of one bracket design over another and really reflects the personal preference of the practitioner.

Customised appliances

According to a patient survey which questioned the various techniques to accelerate treatment offered as options, the most acceptable (54-81%) was a customised appliance as it was most like conventional

fixed appliances and the least invasive. Two examples are SureSmile™ (OraMetrix, Richardson, TX) which uses 3D scans to provide robotically-bent wires to move the teeth into their desired positions, and Insignia™ (Ormco Corporation, Orange CA) which customises the bracket slot to incorporate a straight wire and the brackets are indirectly bonded into the desired positions. In principal, these techniques could reduce error in bracket placement or account for misplacement by bending the wire with more precision.

Two studies concluded that shorter treatment times were achieved by using the Suresmile™ system.[15,16] However, both were retrospective in nature with the inherent limitations in design. As the patients were not prospectively randomised in a clinical trial, the cases may differ as acknowledged in one of the papers in which the Suresmile™ cases were considered less complex.[16] There is also a risk of treatment bias as a clinician who is not 'blinded' to the identity of the appliance can unknowingly 'push' treatment progress or deband slightly sooner in their enthusiasm for a new technique. This is possibly the reason that the initial retrospective SL bracket studies found shorter treatment times whereas later prospective clinical trials found no time difference. The process of robotic bending or a customised slot also cannot totally take into account the play of the arch wire in the bracket-wire interface as a standard finishing wire can allow as much as 12-13° of play or loss of torque control.[17] Similarly, with force diminution in which the force applied from an arch wire interacting with the bracket slot diminishes as the tooth moves so that eventually the force reduces below the threshold where no more movement occurs.[17] This force level will also vary with each individual as there is no identifiable ideal force for all patients.[18]

Currently the level of evidence would be considered very low with a high risk of bias and so the confidence in relying on the current evidence supporting a reduction in treatment time is uncertain. Further research is likely to have an important impact on the confidence in the estimate of any effect.

Medication

The previous methods discussed are aimed at altering the orthodontic mechanics or physics of how force is applied to teeth with the aim of improving efficiency. Medications and the methods discussed further in this article aim at altering a patient's biological response to that force. Medications can also potentially slow movement so an understanding of their effects is important as many patients use prescription and over-the counter medications on a daily basis. Unfortunately, much of the data comes from animal studies rather than human trials and although an insight to their effects is provided, the results cannot be solely relied upon to indicate the effects in humans. Corticosteroid hormones, vitamin D3, parathyroid hormone, and thyroxin have all been shown to increase tooth movement in animal studies.[19] In human trials investigating the application of prostaglandins on tooth movement, the results have suggested a possible acceleration.[20–23] Therefore, drugs blocking their action, such as aspirin and NSAID's could slow orthodontic tooth movement as demonstrated in additional animal studies.[19] Currently, the use of these drugs is limited because of the need for weekly administration and the severe pain caused after the injection. Further research is needed including improving application methods, before prostaglandins could be considered for routine clinical use.

An additional proposed option is the use of autologous platelet rich plasma (PRP) as a substitute for the local injection of cytokines or medications to simulate the effects induced in bone during surgery.[24] Platelets are the initiator of soft and hard tissue wound healing processes and contain growth factors such as the platelet derived growth factor (PDGF), transforming growth factor (TGF), and endothelium growth factors. The technique and effects of submucosal injection of autologous PRP for accelerating orthodontic tooth alignment in cases of anterior crowding was reported to accelerate tooth movement although 15% of participating subjects reported severe pain after injection. This requires further research to confirm this finding as well as record any adverse and dose-dependent effects.

Microvibration

The exact mechanism of alveolar remodelling is not completely understood, but currently there are two main hypotheses related to piezoelectricity generated within the alveolar bone, and secondly, pressure-tension established within the periodontal ligament.[25] Piezoelectricity is generated by orthodontic forces bending alveolar bone to produce an electrical charge which, in turn, induces an osteogenic response.[26] It has been suggested that orthodontic forces should not be continuous as the piezoelectric charges are only created when stress is applied and released.[27] A vibrational appliance may therefore be suitable for initiating these stress-induced charges as forces could be applied and released at a rapid rate. An initial case series report favoured accelerated movement using microvibration.[28] The paper reported that the rates of tooth movement during orthodontic treatment were increased by the use of the device. However, there was no control group for comparison and although the rate of movement reported at 3mm per 28 days seems fast, it was actually only a change in the irregularity index. This index is the sum of 5 measures and

so, in reality, the movement was only 0.6mm per 28 days which is much less impressive.

A recent Cochrane Review[29] which evaluated non-surgical methods of accelerating tooth movement found only two articles of importance .[30,31] Both had potential sources of bias with one paper[30] finding a non-significant 0.6mm difference in irregularity between examined groups after ten weeks of initial alignment. The second study[31] was supported by a grant from the company manufacturing the appliance and the principal author maintains an affiliation with the company. The study reported an increased rate of canine retraction of 0.37 mm/month faster than a control but this increase was deemed clinically unimportant. Importantly, both studies had methodological flaws and the review concluded that the quality of the evidence was very low and therefore the findings considered unreliable. Since this review was published, two higher level RCT's examining the AcceleDent® Aura appliance have been reported. A UK study[32] examined the time for alignment and to the placement of the working wire in the lower arch in extraction cases. The authors concluded that no evidence could be found that supplemental vibrational force can significantly increase the rate of initial tooth alignment or reduce the amount of time required to achieve final alignment. The second paper[33] examined the reduction in irregularity and the change in anterior arch perimeter over the first ten weeks of treatment and found no difference, at any time point, in the lower arch of non-extraction subjects. The same paper also examined the data of appliance-compliant subjects (those using it 75% or more) and still found no difference when using the AcceleDent® Aura appliance. Therefore, currently the higher-level evidence indicates that there is no significant effect of microvibration during initial alignment with fixed appliances.

Low-intensity laser

Low level laser therapy, at a cellular level, causes an increase in RANKL (Receptor Activator of Nuclear Factor Kappa B Ligand) in the periodontal ligament which, in turn, increases the differentiation of precursor cells into activated osteoclasts and potentially increases the rate of orthodontic tooth movement. Most clinical trials investigating canine retraction into premolar extraction sites reported a positive effect caused by laser irradiation on the rate of canine movement.[6] However, a well-designed study with a low risk of bias, found no difference between the laser and control groups.[34] This contradictory finding may be due to the different laser application protocols with the energy density being lower compared with the other studies.[6] The inclusion of this trial affects the results of meta-analysis as one paper indicated that low-intensity laser application had no effect on the rate of orthodontic tooth movement[35] whereas the other concluded that there was weak evidence that low laser therapy plus a corticotomy were associated with accelerated orthodontic tooth movement.[6] However, further research is required before the dual therapy achieves routine application.[6] An additional issue requiring consideration is the possibly that the wavelength used was less important than the energy of the laser and this may vary with different animal species.[36] For example, in dogs, photoradiation seems to accelerate orthodontic movement at a radiant exposure of 5.25 J/cm2, whereas a higher dosage (35.0 J/cm2) movement is delayed.[37]

Photobiomodulation (PBM)

Photobiomodulation, also known as low-level light therapy (LLLT), attempts to use low energy lasers (previously discussed) or light-emitting diodes (LED) to modify cellular biology by the exposure to light in the red to near-infrared (NIR) range (600–1000 nm). The evidence regarding PBM is limited to one trial using the OrthoPulse™ appliance which was conducted by a consulting orthodontist for the company (Biolux Research Ltd.). The study concluded that intraoral PBM increased the average rate of tooth movement resulting in a 54 per cent average decrease in alignment duration compared with a control.[38] However, there were confounding variables including the use of different brackets in the two test groups. The design of the study was poor, lacking appropriate and complete reporting, so that the overall quality of evidence supporting this intervention is currently very low.[6]

Electromagnetic fields

Currently there is one clinical trial which studied the effect of pulsed electromagnetic fields on tooth movement in 10 subjects.[39] Although a higher tooth movement rate of 0.3 mm/month was reported using pulsed electromagnetic fields, the study was poorly conducted and carried a high risk of bias.[6] Considering the unreliable methodology and reporting, the effectiveness of pulsed electromagnetic fields on accelerating orthodontic tooth movement, cannot be determined.[35]

Direct electrical currents

Experiments in cats have reported possible acceleration of orthodontic tooth movement by the use of locally applied electric currents.[40] In a split-mouth study in seven female animals which measured canine retraction by applying an electric current of 20μA for five hours daily, the distance moved was 30 per cent greater on the experimental side after one month

(2.42 ± 0.26 mm vs. 1.89 ± 0.27 mm).[41] Currently there is limited evidence and further research is required to determine if there will be clinical application.

SURGICAL METHODS

Treatment time is dependent upon the rate of tooth movement which in turn is dependent upon the rate of alveolar remodelling. Therefore, it is considered possible that an increase in the rate of tooth movement might be achieved by accelerating the biologic response of the PDL and alveolar bone.[42] A potential mechanism is to 'injure' bone to induce acceleration of the normal physiologic processes involved in wound healing. The local response of tissues to noxious stimuli causes the tissues to regenerate faster than normal in a regional regeneration/remodelling process termed the Regional Acceleratory Phenomena or RAP.[43] Once the repair process has been initiated there is increased levels of cytokine activity around a tooth so that, in theory, the rate of tooth movement during orthodontic therapy can be increased.[44]

Micro-osteoperforations (MOP)

One of the less invasive ways to induce trauma is to perforate the mucosa and bone adjacent to the teeth where the response is desired. An example is a system manufactured by PROPEL Orthodontics (Ossining, NY) in which a disposable stainless steel screw is used to perforate the gingiva and bone usually at three locations adjacent to the tooth or teeth to be moved. A preliminary randomised clinical trial reported a 2.3 fold acceleration in canine retraction.[45] However, this trial is likely biased as the University conducting it owns the patent on MOP and the investigators were not blinded to the side receiving the procedure. The trial was also conducted over a four-week period and so even if there was a difference, it might not continue in the long term as the inflammatory repair process in bone is known to subside over 2-3 months. In contrast, a study in dogs found that there was no difference in the rate of tooth movement and that the effect was limited to cortical bone rather than medullary bone. To be clinically meaningful, any acceleration would need to continue for substantially longer and therefore the procedure likely needs to be repeated at regular intervals. It is unknown if the same effect would be expected on multiple occasions and further research is required to determine if the change is clinically meaningful and therefore justifiable.

Piezocision

An increase in the amount of trauma/invasiveness is produced by the piezocision technique. The technique involves an incision in the buccal gingiva followed by incisions with a Piezo surgical knife to the buccal cortical bone. The procedure relies on the same principle as MOP and currently only case reports without clinical trials have been published. The evidence is therefore weak and the true effectiveness of this technique is unknown.

Corticotomies

A corticotomy involves the creation of shallow perforations or cuts made in the cortical alveolar bone while the trabecular or medullary bone is left intact which differs to an osteotomy. A corticotomy is not a new concept as it was mentioned in 1893 to rapidly reposition palatally-inclined maxillary teeth.[46] The processes associated with corticotomies are similar to the processes associated with normal fracture healing inducing a RAP. The previous techniques of MOP and piezocision penetrate the cortical bone through the overlying tissue without raising a mucoperiosteal flap. In 2001, the Wilcko brothers introduced a procedure that involved raising a mucoperiosteal flap and decorticating the buccal and lingual/palatal sides of alveolar bone and adding particulate bone graft material under the periosteum.[47] The procedure is termed periodontally- accelerated osteogenic orthodontics (PAOO) and has been proposed to increase the volume of the alveolar process, to facilitate arch development, to prevent or even treat fenestrations, and to maximise the metabolic response during orthodontic treatment. The need for the addition of grafting material related to accelerating tooth movement is unclear and no evidence currently exists which establishes improved stability or better depth of bone for movement of teeth or for the prevention of fenestrations and dehiscences.[48] As it is more invasive, the procedure is more costly and has a higher risk of morbidity compared with MOP and piezocision. However, the raising of a flap also means that there is less dense bone and less mature bone around teeth and therefore potentially more rapid tooth movement.[49]

Osteotomies/PDL distraction

A less-involved osteotomy involves interseptal bone reduction in an extraction socket distal to the tooth being retracted. A study evaluating the procedure in a split-mouth design, reported approximately 1.5x faster tooth movement compared with a contralateral control side over the three months of the study. However, no adverse effects were identified and the clinicians were not blinded which can be a potential source of bias. In addition, although the canine was retracted more rapidly, the effect of the surgery dissipated and

so any further accelerated retraction of the incisors was unlikely to occur without additional surgery.

An alternative more invasive osteotomy involves rapid canine retraction through distraction of the dentoalveolus.[24] This technique involves the extraction of a premolar along with its overlying buccal bone. Larger osteotomies are used to fully mobilise the alveolar segment, which includes the canine, by fracturing the surrounding spongy bone around its root from the lingual or palatal cortex. The distraction is started within 3 days of the surgery and the appliance is activated twice per day for a total of 0.8 mm movement per day.

Both of these techniques are limited as they are unable to be applied to the movement of all or multiple teeth. The procedures are basically limited to the retraction of canines following the extraction of first premolars. Special distraction devices need to be manufactured which are bulkier than conventional orthodontic appliances. If conventional coil springs are used the movement seems to be much slower but of a more bodily nature.[50]

Surgery First

In cases requiring orthognathic surgery as part of a treatment plan, a 'surgery-first' approach preceding orthodontic treatment has been suggested. The surgery-first approach treats poor facial aesthetics and the occlusion first and is followed immediately by orthodontic treatment for tooth alignment and occlusal detailing.[51] The suggested criteria for a surgery first approach include patients presenting with well-aligned to mild crowding, a flat to mild curve of Spee, normal to mild proclination/retroclination of incisors, and minimal transverse discrepancies. It may also be indicated in cases in which decompensation is needed. However, one of the disadvantages is that, without pre-surgical orthodontics, it can be very difficult to obtain a stable occlusion immediately after surgery. The majority of cases treated using this approach present with a Class III malocclusion although the surgery-first technique can be applied to Class II as well if all criteria are met. The principle is that by doing the surgery and initiating orthodontic appliance therapy soon after, a RAP is initiated which allows more rapid alignment. However, this phenomena subsides after 2-3 months. In principle, this could have a similar potential as other surgical techniques but currently this has not been the subject of a prospective randomised trial.

SUMMARY OF ACCELERATED TOOTH MOVEMENT

When reviewing the current evidence, one systematic review concluded that, of the non-surgical interventions, only low-level laser therapy provided some evidence of accelerating orthodontic tooth movement.[6] However, a contrary review concluded that LLLT was unable to accelerate orthodontic tooth movement.[35] Currently, the non-surgical methods are associated with very-low quality evidence. Further well-designed RCTs are required to determine whether non-surgical interventions may safely result in a clinically-important reduction in the duration of orthodontic treatment.

Of the surgical interventions, a recent Cochrane review concluded that corticotomy appeared to show promise but the available evidence is of low quality indicating that future research is likely to change the estimate of any effect.[52] A study in dogs, which investigated a corticotomy with a raised flap, demonstrated movement peaked at 22-25 days and then decelerated. However, if a second surgery was performed, accelerated tooth movement was maintained.[53] Similar results when performing a corticotomy with a raised flap were found in adults when canines were retracted following premolar extractions but the effect subsided four months following the procedure.[54] As a result of these studies, the duration of the RAP seems to be in the range of two to three months, after which the rate of tooth movement returns to normal.[49,55] Based upon the limited evidence available, the clinical significance of this temporary acceleration as part of the overall treatment time is questionable. In addition, there are significant additional surgical costs and associated morbidity and, combined with the short duration of the effect, this makes the application of corticotomies on a routine basis, unjustified.[55]

CONCLUSIONS

1 There is limited evidence that LLLT may be of benefit but further investigation is required before routine application is considered.
2 There is low-level evidence to support corticotomy but further research is likely to change the confidence in the estimate of any effect.
3 For all techniques, further well-designed and rigorous RCTs with longer follow-up periods over the entire duration of treatment are required.

CONFLICT OF INTEREST

Receive a grant from the Australian Society of Orthodontists Foundation for Research and Education to help in conducting the study in reference 33.

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