World Journal of Methodology

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DOI: 10.5662/wjm.v4.i3.151

World J Methodol 2014 September 26; 4(3): 151-162
ISSN 2222-0682 (online)
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REVIEW

Dental movement acceleration: Literature review by an alternative scientific evidence method

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Received: January 24, 2014 Revised: July 11, 2014
Accepted: July 17, 2014
Published online: September 26, 2014

Abstract

The aim of this study was to analyze the majority of publications using effective methods to speed up orthodontic treatment and determine which publications carry high evidence-based value. The literature published in Pubmed from 1984 to 2013 was reviewed, in addition to well-known reports that were not classified under this database. To facilitate evidence-based decision making, guidelines such as the Consolidation Standards of Reporting Trials, Preferred Reporting items for systematic Reviews and Meta-analyses, and Transparent Reporting of Evaluations with Nonrandomized Designs check list were used. The studies were initially divided into three groups: local application of cell mediators, physical stimuli, and techniques that took advantage of the regional acceleration phenomena. The articles were classified according to their level of evidence using an alternative method for orthodontic scientific article classification. 1a: Systematic Reviews (SR) of randomized clinical trials (RCTs), 1b: Individual RCT, 2a: SR of cohort studies, 2b: Individual cohort study, controlled clinical trials and low quality RCT, 3a: SR of case-control studies, 3b: Individual case-control study, low quality cohort study and short time following split mouth designs. 4: Case-series, low quality case-control study and non-systematic review, and 5: Expert opinion. The highest level of evidence for each group was: (1) local application of cell mediators: the highest level of evidence corresponds to a 3B level in Prostaglandins and Vitamin D; (2) physical stimuli: vibratory forces and low level laser irradiation have evidence level 2b, Electrical current is classified as 3b evidence-based level, Pulsed Electromagnetic Field is placed on the 4th level on the evidence scale; and (3) regional acceleration phenomena related techniques: for corticotomy the majority of the reports belong to level 4. Piezocision, dentoalveolar distraction, alveocentesis, monocortical tooth dislocation and ligament distraction technique, only had case series or single report cases (4th level of evidence). Surgery first and periodontal distraction have 1 study at level 2b and corticision one report at level 5. Multiple orthodontic acceleration reports on humans were identified by an alternative evidence level scale, which is a simple and accurate way of determining which techniques are better and have a higher rate of effectiveness. The highest level of evidence for a specific procedure to accelerate orthodontic dental movement up to October 2013 was surgery first followed by low level laser application, corticotomy and periodontal distraction located on level 2, recommendation grade b from this proposed scientific evidence-based scale.

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Key words: Orthodontic movement; Evidence-based dentistry; Dental movement acceleration

Core tip: Orthodontic systematic reviews of randomized clinical trials, meta analysis and meta analysis network are difficult to develop due to a lack of high quality randomized clinical trials related to orthodontic therapies. The correct classification of the scientific literature fol-

lowing the evidence-based hierarchy facilitates the answers to specific clinical questions, and thus its application in every scientific subject. The resources available to speed up orthodontic movement had been widely examined. Due to a lack of evidence-based strength, the latter method cannot be taken into account in clinical protocols, thus we are left with the main already clinically proven methods: local injection of cellular mediators, physical stimuli, and surgically assisted orthodontics.

Domínguez A, Velásquez SA. Dental movement acceleration: Literature review by an alternative scientific evidence method. *World J Methodol* 2014; 4(3): 151-162 Available from: URL: http://www.wjgnet.com/2222-0682/full/v4/i3/151.htm DOI: http://dx.doi.org/10.5662/wjm.v4.i3.151

INTRODUCTION

Any clinical inquiries in orthodontics should only be responded to after a thorough and critical analysis of the available scientific literature on the subject in question. Orthodontic patients deserve the highest level of care that is only possible through the strict use of the best available current information[1].

The best method for optimal information analysis involves stratified levels of evidence and grades of recommendations, regardless of the current classification. Evidence Based Dentistry is the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of each patient[2-5].

The Oxford University evidence-based classification system includes every study carried out in humans using a very complete system (Table 1). The OCEBM levels have the advantage of offering levels of evidence for therapy, prognosis, diagnosis, differential diagnosis, and economic analysis all in a single table. In 2011, this system was simplified and modified, but left out the inclusion or possible adaptation of orthodontic scientific studies (Table 2).

In Table 3 an alternative scientific method to classificate scientific articles related to orthodontic therapies is proposed.

Orthodontic systematic reviews of randomized clinical trials (RCTs), meta-analysis and meta-analysis network are difficult to develop due to a lack of high quality randomized clinical trials related to orthodontic therapies. In the future, orthodontics ideally should develop and include prospective meta-analyses, thus avoiding the classic limitations of previous randomized clinical trials. The correct classification of the scientific literature following the evidence-based hierarchy facilitates the answers to specific clinical questions, and thus its application in every scientific subject.

The resources available to speed up orthodontic movement have been widely investigated in humans and animals. Due to a lack of evidence-based strength the latter cannot be taken into account in clinical protocols, thus we are left with the main already clinically proven methods: local injection of cellular mediators, physical stimuli, and surgically assisted orthodontics.

The main objective of this literature review was to analyze successful publications and the methods used to speed up orthodontic treatment and determine which publications carry a high evidence-based value.

LITERATURE SEARCH

The following clinical question was asked: Is there a way to move a tooth faster than conventional orthodontics? In order to begin the related literature search, the available methods to accelerate dental movement in adults were researched to determine which of these methods showed the highest level of scientific evidence.

Literature published in Pubmed from 1984 to October 2013 was reviewed, in addition to well-known reports that were not classified under this database.

To facilitate evidence-based decision making, guidelines such as the Consolidation Standards of Reporting Trials, Preferred Reporting Items for Systematic Reviews and Meta-analyses, and Transparent Reporting of Evaluations with Non-randomized Designs check list were used[6-8].

INCLUSION CRITERIA

Studies in any language and controlled or randomized clinical studies in humans.

EXCLUSION CRITERIA

In vitro or animal studies, reports that included non-effective methods to speed up dental movement and reports on the acceleration of dental movement that did not evaluate time in their research.

The studies were initially divided into three groups: local application of cell mediators, physical stimuli, and techniques that took advantage of the regional acceleration phenomena.

The articles were classified according to their level of evidence as shown in Table 3.

LOCAL APPLICATION OF CELL MEDIATORS

Local application of prostaglandins

The highest level of evidence corresponds to a 3B level from 3 publications: Yamasaki *et al*[9] developed a study which was divided into three phases. The first phase was on premolars which were to be extracted, on one side, they used sub mucosal injections of prostaglandin E1 (PGE1) and on the other side a vehicle substance was injected. The rate of movement of the teeth towards the buccal area was approximately 2-fold at the site of PGE1 injection. A similar result was obtained in the second phase where PGE1 injections were administered in the canine retraction areas for a period of 3 wk. The third

Table 1 The Oxford University evidence based classification applies and includes all studies performed on humans using a very complete system

Level	Therapy/ prevention, aetiology/harm	Prognosis	Diagnosis	Differential diagnosis/ symptom prevalence study	Economic and decision analyses
1a	SR (with homogeneity) of RCTs	SR (with homogeneity) of inception cohort studies; CDR" validated in different populations	SR (with homogeneity) of Level 1 diagnostic studies; CDR" with 1b studies from different clinical centres	SR (with homogeneity) of prospective cohort studies	SR (with homogeneity) of Level 1 economic studies
1b	Individual RCT (with narrow confidence interval")	Individual inception cohort study with > 80% follow-up; CDR" validated in a single population	Validating cohort study with good reference standards; or CDR" tested within one clinical centre	Prospective cohort study with good follow-up	Analysis based on clinically sensible costs or alternatives; systematic review(s) of the evidence; and including multi-way sensitivity analyses
1c	All or none	All or none case-series	Absolute SpPins and SnNouts	All or none case-series	Absolute better-value or worse-value analyses
2a	SR (with homogeneity) of cohort studies	SR (with homogeneity) of either retrospective cohort studies or untreated control groups in RCTs	SR (with homogeneity) of Level > 2 diagnostic studies	SR (with homogeneity) of 2b and better studies	SR (with homogeneity) of level > 2 economic studies
2b	Individual cohort study (including low quality RCT; *e.g.*, < 80% follow-up)	Retrospective cohort study or follow-up of untreated control patients in an RCT; Derivation of CDR" or validated on split-sample only	Exploratory cohort study with good reference standards; CDR" after derivation, or validated only on split-sample or databases	Retrospective cohort study, or poor follow-up	Analysis based on clinically sensible costs or alternatives; limited review(s) of the evidence, or single studies; and including multi-way sensitivity analyses
2c	"Outcomes" Research; ecological studies	"Outcomes" Research		Ecological studies	Audit or outcomes research
3a	SR (with homogeneity) of case-control studies		SR (with homogeneity) of 3b and better studies	SR (with homogeneity) of 3b and better studies	SR (with homogeneity) of 3b and better studies
3b	Individual case-control study		Non-consecutive study; or without consistently applied reference standards	Non-consecutive cohort study, or very limited population	Analysis based on limited alternatives or costs, poor quality estimates of data, but including sensitivity analyses incorporating clinically sensible variations
4	Case-series (and poor quality cohort and case-control studies)	Case-series (and poor quality prognostic cohort studies)	Case-control study, poor or non-independent reference standard	Case-series or superseded reference standards	Analysis with no sensitivity analysis
5	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on physiology, bench research or "first principles"	Expert opinion without explicit critical appraisal, or based on economic theory or "first principles"

Produced by Bob Phillips, Chris Ball, Dave Sackett, Doug Badenoch, Sharon Straus, Brian Haynes, Martin Dawes since November 1998. Updated by Jeremy Howick March 2009. RCT: Randomized clinical trials; SR: Systematic Review.

phase involved routine canine retraction and PGE1 was applied only on one side, which resulted in 1.6-fold faster movement on the treated side. The researchers did not find any adverse macroscopic effects either in the gum tissue or the alveolar bone. Only mild pain related to the dental movement was observed.

A second preliminary study was performed in 5 patients by Spielmann *et al*[10], with the common objective of assessing the effect of PGE1 on tooth movement. This differed from the previous study in that force was applied to the upper right and left premolars which were to be extracted later during the course of routine orthodontic treatment, and a reciprocal force was used. The method consisted of the local administration of anesthesia 0.1 mL of 0.01% (w/v) PGE1 solution in saline which was injected under the palatal mucoperiosteum to the test tooth and 0.1 mL saline palatal to the contralateral control tooth. Injections were repeated at weekly intervals.

On average the experimental teeth moved 3 times faster than the control teeth without any pathological changes.

Patil *et al*[11] in 2005, performed a clinical assay on 14 patients who were injected for three days with a dose of 1 g of PGE1 (3 g in total), using lidocaine as a vehicle substance in the distal buccal area of canines retracted with Niti open coils. The left side only received a vehicle substance as a control. The patients were monitored for 60 d and the authors concluded that following a minimal dose of PGE1 an increase in the rate of movement was

Table 2 Oxford centre for evidence-based medicine 2011 levels of evidence

Question	Step 1 (Level 1[1])	Step 2 (Level 2[1])	Step 3 (Level 3[1])	Step 4 (Level 4[1])	Step 5 (Level 5)
How common is the problem?	Local and current random sample surveys (or censuses)	Systematic review of surveys that allow matching to local circumstances[2]	Local non-random sample[2]	Case-series[2]	N/A
Is this diagnostic or monitoring test accurate? (Diagnosis)	Systematic review of cross sectional studies with consistently applied reference standard and blinding	Individual cross sectional studies with consistently applied reference standard and blinding	Non-consecutive studies, or studies without consistently applied reference standards[2]	Case-control studies, or "poor or non-independent reference standard[2]	Mechanism-based reasoning
What will happen if we do not add a therapy? (Prognosis)	Systematic review of inception cohort studies	Inception cohort studies	Cohort study or control arm of randomized trial[1]	Case-series or case-control studies, or poor quality prognostic cohort study[2]	N/A
What are the COMMON harms? (Treatment Harms)	Systematic review of randomized trials or n-of-1 trials	Randomized trial or observational study with dramatic effect	Non-randomized controlled cohort/follow-up study[2]	Case-series, case-control studies, or historically controlled studies[2]	Mechanism-based reasoning
What are the RARE harms? (Treatment Harms)	Systematic review of randomized trials, systematic review of nested case-control studies, nof-1 trial with the patient you are raising the question about, or observational study with dramatic effect	Individual randomized trial or (exceptionally) observational study with dramatic effect	Non-randomized controlled cohort/follow-up study (post-marketing surveillance) provided there are sufficient numbers to rule out a common harm. (For long-term harms the duration of follow-up must be sufficient)[2]	Case-series, case-control, or historically controlled studies[2]	Mechanism-based reasoning
Is this (early detection) test worthwhile?	Systematic review of randomized trials or n-of-1 trial	Randomized trial or (exceptionally) observational study with dramatic effect			
Is this (early detection) test worthwhile? (Screening)	Systematic review of randomized trials	Randomized trial	Non-randomized controlled cohort/follow-up study[2]	Case-series, case-control, or historically controlled studies[2]	Mechanism-based reasoning

[1]Level may be graded down on the basis of study quality, imprecision, indirectness (study PICO does not match questions PICO), because of inconsistency between studies, or because the absolute effect size is very small. Level may be graded up if there is a large or very large effect size; [2]As always, a systematic review is generally better than an individual study. OCEBM Levels of Evidence Working Group. "The Oxford 2011 Levels of Evidence". Oxford Centre for Evidence-Based Medicine. http://www.cebm.net/index.aspx?o=5653.

evident compared to the control group.

Vitamin D

The highest level of evidence 3B corresponds to an original Spanish article by Blanco *et al*[12]. The main objective of this study was to determine if a systemic dose of calcitrol supplement (0.25 μg), accelerates canine retraction movement over 60 d as compared to a control group.

Twenty patients (20 ± 5 years) whose canines were retracted using a stainless steel loop by applying a 75 g force when necessary every 15 d were included in this study. The subjects were randomly assigned to two groups: 10 received an oral dose of calcitrol 0.25 μg daily for 60 d and were monitored 10 times; the remaining 10 subjects acted as controls. An increased rate of movement was found in the experimental group ($P = 0.00028$). The researchers concluded that the average speed of movement was faster in the experimental group than in the control group.

PHYSICAL STIMULI

Vibratory forces

These are placed on the 4th level of the evidence scale, and the publications include a case series published by Kau in 2009[13] and 2010[14]. The main objective in the first publication was to report data resulting from use of the Acceledent System. In 2010, the clinical effects of the cyclical force generated by the device (Acceledent) on teeth and the average treatment time were reported. In addition, the levels of patient compliance and satisfaction were assessed. The sample size was the same for the two studies, 14 patients, 11 during leveling and alignment and 3 with space closure. The results of both of these studies were within the range of 0.526 mm of movement per week using Acceledent type I for 20 min daily during 6 consecutive months. Good patient compliance and satisfaction were observed.

Pulsed electromagnetic field

This is classified 3b evidence based on the study by Showkatbakhsh *et al*[15] in 2010, who showed that a pulsed electromagnetic field was capable of accelerating orthodontic tooth movement. The canines on one side in 10 patients who required canine retraction were exposed to a pulsed electromagnetic field (PEMF); the canines on the contralateral side in the same patients were not exposed to the PEMF. A circuit and a watch battery were used to

Table 3 Levels of evidence for therapies in orthodontics

Level	Therapy
	Prospective Meta analysis
	Meta analysis
1a	SR (with homogeneity) of RCTs
1b	Individual RCT
2a	SR (with homogeneity) of cohort studies
2b	Individual cohort study, CCTs and low quality RCT
3a	SR (with homogeneity) of case-control studies
3b	Individual Case-Control study, low quality cohort study and short time split mouth design
4	Case-series, low quality case-control study and non systematic review
5	Expert opinion

RCTs: Randomized clinical trials; SR: Systematic review; CCTs: Controlled clinical trials.

generate the PEMF (1 Hz). The generator was embedded in a removable device. Foil was used to prevent PEMF exposure in the control group. Showkatbakhsh *et al*[15] reported that the accumulative distance moved was significantly larger in the experimental group (5.0 ± 1.3 mm *vs* 3.5 6 ± 1.6 mm, $P \geqslant 0.001$) after 5 ± 0.6 mo.

Electrical current

Kim *et al*[16] demonstrated that an electrical current was capable of accelerating orthodontic tooth movement. Moreover, as only females (7) were included in this study, we do not know the effects of the electrical current in males. The electric appliance was set in the maxilla to provide a direct electric current of 20 microns. The maxillary canine on one side represented the experimental side, and the maxillary canine on the other side represented the control. The experimental canine received orthodontic force and an electric current. The control side received orthodontic force only. An electric current was applied to the experimental canines for 5 h daily, the authors showed that the accumulative distance moved was significantly larger in the experimental group after 1 mo (2.42 ± 0.26 mm *vs* 1.89 ± 0.27 mm). The electrical current was delivered to the mucosa of canines through a fixed electrical appliance assembly (20 MA, 5 h per day). This report is classified as 3b evidence based level.

Low level laser irradiation

Evidence based level 3b: Cruz *et al*[17] were the first to publish research on the effects of low level laser irradiation (LLLI) on the average speed of dental movement. The sample consisted of 11 patients who received a 150 g maxillary canine retraction force bilaterally for 2 mo, one side was irradiated and the other side was used as a control. Irradiation standards were wavelength 780 nm, power 20 mW, energy flow 2 J, energy density 5 J/cm^2, and total dose 8 J. The authors registered a 34% increase in the speed of dental movement on the experimental side compared to the control side[17].

Limpanichkul *et al*[18] used a different set of standards during laser application: 860 nm, 100 mW, 25 J/cm^2, 18.4 J around the experimental tooth (buccal mucosa, distal and palatal) 4 times over a month for a total dose of 294.4 J. The results did not show significant statistical differences between the experimental and control sides, concluding that the dose used (5 J/cm^2) was too low to achieve an increase in the rate of dental movement. To assess the effects of the laser (Ga-Al-As) during the retraction phase in canines, Youssef *et al*[19] irradiated the cervical, middle and the apical surface of the tooth on its buccal and palatal sides with 809 nm and 100 mW for 40 s; the total dose to the right upper and lower canines was 8 J (2 × 40 s at 100 mW), the left side was used as a control. The laser was applied using intervals of 0, 3, 7 and 14 d. The retraction coil was activated on day 21 for both sides. The study results showed a significant increase in movement rate for the irradiated canines when compared to the control[20].

Sousa *et al*[20] evaluated the effect of LLLI on the speed of orthodontic dental movement in 26 canines with retraction NiTi coil springs (150 g). 13 were irradiated (780 nm, 20 mW, 10 s, 5 J/ cm^2), and the other 13 were used as controls. The groups were followed for 4 mo with a total of 9 laser irradiations during that time. The authors concluded that the laser group, using the parameters described, showed an increased rate of orthodontic dental movement, and this could lead to a reduction in treatment time[21].

Evidence level 2b: Dominguez *et al*[21] in 2010 in a prospective cohort study, started at 5 mm crowding non-extraction and finished with a sample of 45 patients between 20 and 30 years old. The experimental group was irradiated at each appointment 1 mm away from the mucosa on the buccal and palatal sides, following the long axis of the tooth for 22 s on each surface. The control group did not receive laser irradiation.

The measurement unit used was days of treatment, the dosage and parameters of irradiation were: 830 nm, 100 mW, energy density 80 J/cm^2, an active laser point of 0.028 cm^2 and the energy was 2.2 J. These parameters allowed a reduction of 30% in the LLLI treated group during the total treatment time.

REGIONAL ACCELERATION PHENOMENA RELATED TECHNIQUES

Regional acceleration phenomena (RAP) healing is a complex physiologic process with dominant features involving accelerated bone turnover and decreases in regional bone densities. Following surgical wounding of cortical bone, RAP potentiates tissue reorganization and healing by a transient burst of localized hard and soft tissue remodeling[22-24].

Corticotomy

The majority of reports on corticotomy belong to level 4 in the scale of evidence.

In 1959, Kole[25] using the crowns of the teeth as handles, believed that he was able to move the blocks of bone independently of each other as they were only connected by the less-dense medullary bone. He reported that combining orthodontics with corticotomy led to active tooth movement in adult orthodontic cases in 6 to 12 wk. The technique was known as "bony block". The interproximal corticotomy cuts were extended through the entire thickness of the cortical layer, just barely penetrating into the medullary bone. These vertical cuts were connected beyond the apices of the teeth with a horizontal osteotomy cut extending through the entire thickness of the alveolus, essentially creating blocks of bone in which one or more teeth were embedded.

Gantes *et al*[26] showed in 5 patients, that the corticotomy procedure caused minimal changes in the periodontal attachment apparatus. The surgical procedure included intracrevicular incisions and an elevation of buccal and lingual mucoperiosteal flaps. Buccal and lingual vertical grooves penetrating the cortical bone were then made between the roots. These grooves were extended from just below the interproximal alveolar bone margin to beyond the apex levels of the teeth. Buccal and lingual horizontal grooves joined the apical extensions of the vertical grooves. The orthodontic appliance was activated immediately upon wound closure.

In 1991, Suya *et al*[27] reported surgical orthodontic treatment of 395 adult Japanese patients with an improved surgical procedure that he referred to as "corticotomy-facilitated orthodontics."

The authors who have major quantities of scientific reports are the Wilcko[28-33] brothers starting in 2000 up to 2009 and these techniques are now known as Periodontally Accelerated Orthodontic and Osteogenic Techniques. Their reports show high success in acquiring accelerated dental movement which they attribute to an osteoclastic phase or catabolic phase from the regional acceleration phenomena. The Wilcko brothers introduced a technique combining alveolar corticotomies and bone grafting to prevent the risk of dehiscence and fenestration, while increasing the scope of orthodontic corrections. In this conventional approach, cortical incisions circumscribing the roots are made on both the buccal and palatal side following full thickness mucoperiosteal flaps. The bone graft is then placed facing the teeth to be moved and the flaps are then repositioned and sutured at the papilla.

This highly effective technique was also proven to be useful for the intrusion of overerupted molars as reported by Hwang *et al*[34] and Oliveira *et al*[35,36] and for incisive retraction by Germec *et al*[37].

In the study by Akay *et al*[38] all individuals received combined subapical corticotomy and a skeletal anchorage procedure, and intrusion forces of 200 to 300 g were applied to the attachments of each molar and both premolars for 12 to 15 wk. Their results indicated that the use of combined treatment with corticotomy and skeletal anchorage provided safe and noncompliant intrusion of posterior teeth in a short period and may be regarded as an alternative method for skeletal open bite correction in adults who reject orthognathic surgery.

Choo *et al*[39] performed a study to assess the results of surgical accelerated orthodontics in protrusive adults. 24 adults with maxillary or bimaxillary protrusion were treated with speedy surgical orthodontics, including maxillary perisegmental corticotomy followed by orthopedic en-mass retraction against C-palatal miniplate anchorage.

The authors found that the average total treatment time was 20 mo (range, 11-42 mo) and concluded that surgically accelerated orthodontics could be an excellent treatment alternative for adult patients with severe maxillary or bimaxillary protrusion.

In 2012, Bhat *et al*[40] knowing that significant acceleration in orthodontic tooth movement had been extensively reported studied a combination of selective alveolar decortication and bone grafting surgery. The latter was responsible for the increased scope of tooth movement and long-term improvement in the periodontium. A study was carried out in six patients diagnosed with class I malocclusion and bimaxillary protrusion. A modified corticotomy procedure was performed. Active orthodontic treatment began within 1 wk after surgery and the patients were followed up. The mean treatment time for these patients was 17.4 mo, and distalization of the canines was mostly completed within 8.5 mo.

Corticotomy studies level 3b: Fischer[41] evaluated the effectiveness of corticotomy comparing six consecutive patients presenting with bilaterally impacted canines. One canine was surgically exposed using a conventional surgical technique, while the contralateral canine was exposed using a corticotomy-assisted technique. The results showed a reduction in treatment time of 28%-33% for the corticotomy-assisted canines.

Aboul-Ela *et al*[42] evaluated 13 patients requiring the therapeutic extraction of the maxillary first premolars, with subsequent retraction of the maxillary canines. By using miniscrews as anchorage, canine retraction was initiated *via* closed nickel-titanium coil springs applying 150 g of force per side. Corticotomy-facilitated orthodontics was randomly assigned to one side of the maxillary arch of the canine-premolar region, and the other side served as the control. The average daily rate of canine retraction was significantly higher on the corticotomy side than the control side by 2-fold during the first 2 mo after corticotomy surgery. This rate of tooth movement declined to only 1.6-fold higher in the third month and to 1.06-fold by the end of the fourth month.

A study was conducted by Lee *et al*[43] on 65 Korean adult female patients with bimaxillary dentoalveolar protrusion to compare the orthodontic treatment outcomes of anterior segmental osteotomy and corticotomy-assisted orthodontic treatment. It was concluded that orthodontic treatment and corticotomy-assisted orthodontic treatment were indicated for patients with severe incisor proclination with normal basal bone position, although corticotomy-assisted orthodontic treatment had the advantage of shorter treatment duration. Anterior segmental osteotomy is recommended for bimaxillary dentoalveolar protrusion patients with gummy smile, basal bone prognathism, relatively normal incisor inclination, and relatively underdeveloped chin position.

Corticotomy study level 2b: Shoreibah *et al*[44] conducted a study to evaluate the effect of corticotomy-facilitated orthodontics (CFO) in adults using a further modified technique *vs* traditional therapy in orthodontic tooth movement. The sample included twenty orthodontic patients with moderate crowding of the lower anterior teeth which were randomly divided and treated with either a modified technique of corticotomy-facilitated orthodontic tooth movement (Group Ⅰ) or conventional orthodontic therapy (Group Ⅱ). The authors showed that there was a statistically significant difference between the two groups regarding treatment duration: 17.5 ± 2.8 wk in the CFO group and 49 ± 12.3 wk in the conventional orthodontic therapy group.

Piezocision

To overcome the disadvantages of other corticotomy techniques, Dibart *et al*[45] introduced a minimally invasive, flapless procedure combining piezo surgical cortical micro-incisions with selective tunneling that allows for bone or soft-tissue grafting. Due to their small size and precision, piezoelectric cutting inserts realize precise osteotomies without the risk of osteonecrosis[46]. The authors removed the lingual flap by performing only vestibular incisions, but the elevation of a flap prior to the corticotomy was maintained, thus only relatively reducing surgical time and postoperative discomfort.

Combined with proper treatment planning and a good understanding of the biological events involved, this novel technique can locally manipulate alveolar bone metabolism in order to obtain rapid and stable orthodontic results. Piezocision allows for rapid correction of severe malocclusions without the drawbacks of traumatic conventional corticotomy procedures. Previous reports and those published in 2011 are case series or single case reports (4th level of evidence) which conclude that piezocision is an effective therapy to reduce treatment time when compared to treatments such as Invisalign[47,48].

According to Uribe *et al*[49] corticotomies can potentially reduce the treatment time dramatically in patients who require a significant amount of molar protraction. The authors reported a single case (level 4), of a patient with agenesis of the lower second premolars, after the extraction of primary second molars, mucoperiostal flaps were elevated and interproximal vertical corticotomies were performed on the labial aspect of the mandibular molars with a piezo surgical microsaw. The vertical groove corticotomies were performed mesial to the first and second molars bilaterally and extended just below the crestal bone to the apex. Dried-freeze demineralized bone allograft was packed on the buccal surface covering the grooves and exposed labial cortical bone surface, including a dehiscence on the first molar. The edentulous zone was closed in ten months.

Dentoalveolar distraction

Dentoalveolar distraction (DAD) was performed by making monocortical perforations on alveolar bones around the canines, followed by distracting the canine using distractors.

The scientific literature shows the following case series and a single case report (evidence level 4).

According to Kişnişci *et al*[50] the concept of distraction osteogenesis for rapid orthodontic tooth movement is promising and feasible for clinical practice.

They reported a case series of eleven patients whose first premolars were extracted, and the buccal bone was carefully removed. After wound closure, a special orthopedic device was mounted and cemented to the first molar and canine teeth. Distraction started the same day at the rate of 0.4 mm twice a day and continued until adequate movement of the canine teeth was achieved.

According to Işeri *et al*[51] the dentoalveolar distraction technique is an innovative method that reduces overall orthodontic treatment time by nearly 50%. The authors conducted a study that consisted of 20 maxillary canines in 10 subjects, the first premolars were extracted, the dentoalveolar distraction surgical procedure was performed, and a custom-made intraoral, rigid, tooth-borne distraction device was put in place. The canines were moved rapidly into the extraction sites in 8 to 14 d, at a rate of 0.8 mm per day and full retraction of the canines was achieved in a mean time of 10.05 (± 2.01) d. The same results with the same sample characteristics were published by Akhare *et al*[52] in 2011.

Kurt *et al*[53] reported a 15-year-old skeletal and dental class Ⅱ female patient, with an overjet of 9 mm who was treated by DAD osteogenesis. A custom-made, rigid, tooth-borne intraoral distraction device was used for rapid canine retraction. Osteotomies surrounding the canines were performed to achieve rapid movement of the canines within the dentoalveolar segment, in compliance with distraction osteogenesis principles. The amount of canine retraction was 7.5 mm in 12 d at a rate of 0.625 mm per day.

Kisnisci *et al*[54] reported Dentoalveolar Transport Osteodistraction to distalized canines in 73 alveolar cleft cases. Overall management of selected cases with wider defects may also be optimized and simplified through the transport distraction of a tooth-bone segment. The osteotomy involves designing a partial-thickness bony segment of the transportation of a canine tooth to close the gap resulting from the extraction of the first premolar without a discontinuity defect.

Periodontal distraction

Periodontal distraction was performed by making vertical grooves on the mesial side of the first premolar extraction sockets followed by the same distraction techniq ue as used in DAD. Liou *et al*[55] performed the procedure in fifteen consecutive orthodontic patients, in which twenty-six canine distractions, including 15 upper and 11 lower canines, were carried out with custom made, tooth-borne, intraoral distraction devices. Right after the first premolar extraction, the interseptal bone distal to the canine was undermined with a bone bur, grooving vertically inside the extraction socket, along the buccal and lingual sides, and extending obliquely toward the base of the interseptal bone to weaken its resistance. The interseptal bone was not cut through mesiodistally toward the canine. The intraoral distraction device was delivered for canine distraction right after the first premolar extraction. It was activated 0.5 to 1 mm/d. The authors concluded that the periodontal ligament can be distracted just like the midpalatal suture in rapid palatal expansion. By using this concept, canines can be distracted distally 6.5 mm in 3 wk without significant complications.

Other case series (Level 4) reports are as follows: Gürgan *et al*[56] in 2005, during a 12 mo follow-up period, but without a control group, analyzed 36 maxillary canines until full retraction of the canines was achieved in 10.36 ± 1.93 d (range 8-14 d) at a rate of 0.8 mm/d using a custom-made intraoral rigid tooth-borne distraction device. The periodontal follow-up results allowed them to conclude that dentoalveolar distraction is an innovative technique with no unfavourable long-term effects on the gingival tissues of rapidly retracted canine teeth.

Sukurica *et al*[57] in a six month follow-up study, evaluated twenty canine retraction movements in eight patients. The distraction procedure was completed in 12 to 28 d (mean 14.65 ± 3.49 d). The distal displacement of the canines ranged from 3 to 8 mm (mean 5.35 ± 1.22 mm).

Kumar *et al*[58] concluded that canines can be rapidly retracted by periodontal ligament distraction without complications. The analysis was carried out in 16 upper canines in eight patients who required first premolar extractions. The upper first premolars were extracted and the interseptal bone distal to each canine was thinned and undermined surgically. Custom-built distractors were placed and activated immediately to distract the canines into the extraction spaces. The canines were retracted to proximal contact with the second premolars in 20.33 ± 1.87 d.

In a larger study of 43 canine teeth in 18 (seven male and 11 female) patients who required first premolar extractions conducted by Sayin *et al*[59], the canine retraction was carried out with teeth using semi-rigid, individual tooth-borne distractors. The maxillary canines were distalized an average of 5.76 mm with 11.47 degrees distal tipping. The mean distal movement of the mandibular canines was 3.5 mm with 7.16 degrees distal tipping.

In a split mouth randomized clinical trial without blinded outcome assessment (level 2b) involving 30 patients, Mowafy *et al*[60] evaluated the amount and time of canine retraction concomitant with periodontal ligament distraction using intermittent and continuous forces. For each patient, one side was randomly allocated to receive a screw-based dental distractor, and the other side received a continuous force coil spring distractor. The authors found that the average time needed for canine retraction was 5.3 ± 1.3 wk.

Mtdld technique

Case series: Evidence level 4: Vercellotti *et al*[61], developed a surgical-orthodontic technique [The monocortical tooth dislocation and ligament distraction (MTDLD) technique] to maximize the rapidity of dental movement and prevent damage to the periodontal tissues. During the procedure they performed a microsurgical corticotomy around each tooth, buccal monocortical tooth dislocation and palatal ligament distraction movement and the immediate application of biomechanical force. The report included 8 patients with malocclusion who underwent the procedure and the authors concluded that compared to traditional orthodontic therapy, the average treatment time with the MTDLD technique in the mandible and maxilla was reduced by 60% and 70%, respectively.

In 2011, Bertossi *et al*[62] performed piezosurgical bone cuts to 10 patients affected by different dental malformations to determine the effects of a shorter treatment time. This method (MTDLD technique) is simple, and performing osteotomic lines laterally and apically to the tooth radix on the bone has proved useful in reducing the treatment time. In addition, the technique is very easy to use and has a low incidence of complications. In 5 patients with dental ankylosis, dental repositioning was achieved within 18 to 25 d and in another 5 preoperative patients affected by maxillary hypoplasia and transverse maxillary diameter reduction, in 68 to 150 d.

In 2010, Kharkar *et al*[63] conducted a non-randomized pilot study. The aim of this study was to assess and evaluate the best approach to reduce the overall orthodontic treatment time by means of distraction osteogenesis. The sample consisted of six patients, comprising two groups, who were compared using two different surgical techniques: dento-alveolar distraction and periodontal distraction to bring about rapid canine retraction using a designed intra-oral distractor. Dento-alveolar distraction was superior to periodontal distraction in the time required for retraction, canine tipping, anchorage loss and amount of external root resorption. As a controlled clinical trial with a small sample this was classified as evidence level 3b.

Comparing acceleration techniques and amount of dental movement, Long *et al*[64] in 2013 conducted a systematic review with an evidence level 3 that included cases and control studies and concluded that corticotomy its an effective and safe method to accelerate dental movement in orthodontics. Alveolar or periodontal distractions are promising methods to promote orthodontic movement acceleration, but they lack enough convincing evidence to support them.

Alveocentesis (micro-osteoperforations)

Evidence level 4: Nicozisis[65] showed clinical examples of orthodontic treatments using propel, used in rotation, molar uprighting, Quicker Pre-surgical Orthodontics, intrusion and crowding. In addition, other reports which can be used successfully include, but are not limited to, TADs, Invisalign®, Sure Smile,® and conventional braces.

This includes the study by Teixeira *et al*[66] in 2010, and the results of both animal and clinical studies have demonstrated that the PROPEL System using the Alveocentesis technique decreases orthodontic treatment time by 50%-60% or more in combination with any type of orthodontic force.

Surgery first

The performance of surgery without orthodontic preparation (*i.e.*, "surgery first"), followed by regular postoperative dental alignment, was proposed by Nagasaka *et al*[67]. The authors used this approach to correct skeletal class Ⅲ malocclusion with the aid of skeletal anchorage system orthodontics. The total treatment time was noticeably reduced. In addition, preoperative profile worsening due to incisor decompensation was avoided and immediate profile improvement after surgery was greatly appreciated by the patient.

According to Liou *et al*[68], the advantages of the surgery-first approach are as follows: (1) the patient's chief complaint, dental function, and facial esthetics are achieved and improved at the beginning of treatment; (2) the entire treatment period is shortened to 1 to 1.5 years or less depending on the complexity of the orthodontic treatment; and (3) the phenomenon of postoperative accelerated orthodontic tooth movement reduces the difficulty and treatment time of orthodontic management in the surgery-first approach.

Liou *et al*[69] conducted a study in twenty-two adult patients, who received Le Fort I osteotomy of the maxilla and bilateral sagittal split of the mandible for dentofacial deformities. Crevicular fluid levels of serum alkaline phosphatase and C-terminal telopeptide of type I collagen were determined, as well as tooth mobility of the maxillary and mandibular incisors in these patients. The results support the hypothesis that the phenomenon of postoperative accelerated orthodontic tooth movement is due to the increase in osteoclastic activity and metabolic changes in the dentoalveolar caused by orthognathic surgery. The orthognathic surgery triggers 3 to 4 mo of higher osteoclastic activity and metabolic changes in the dentoalveolar postoperatively, which possibly accelerates postoperative orthodontic tooth movement.

Studies on surgery first are mainly case reports and case series (Evidence based level 4).

Uribe *et al*[49], described a 16-year-old female with a concave profile and class Ⅲ malocclusion, who received a surgical maxillary LeFort 1 advancement and completed her whole treatment within eight months. This was followed by a number of successful case reports that showed short treatment time for ortho- surgical cases using the surgery first approach in class two and three patients: Sugawara *et al*[70], Yu *et al*[71], Villegas *et al*[72] (asymmetrical class Ⅲ), Baek *et al*[73], and Oh *et al*[74].

Hernández-Alfaro *et al*[75] reported 2 cases successfully treated with bimaxillary surgery first. In patient 1, the total orthodontic treatment required 250 d. Arch settlement and leveling achieved a Class I relationship, with adequate root parallelism that was stable at follow-up 1 year later. For patient 2, the total orthodontic treatment lasted 185 d, after which an adequate Class I occlusion and an esthetically balanced profile was achieved.

In 2013, Hernández-Alfaro *et al*[76] reported treating forty-five patients with a surgery first approach. Selected cases presented with symmetrical skeletal malocclusions with no need for extractions or surgically assisted rapid palatal expansion. Standard orthognathic osteotomies were followed by buccal interdental corticotomies to amplify the regional acceleratory phenomenon. Miniscrews were placed for postoperative skeletal stabilization. Orthodontic treatment began 2 wk after surgery. Mean duration of orthodontic treatment was 37.8 wk (range, 24 to 52 wk). Orthodontic retention followed in all cases. An average of 22 orthodontic appointments (range, 14 to 29) occurred. The authors concluded that the surgery first approach significantly shortened total treatment time and was favorable in patients and orthodontists. Nevertheless, careful patient selection, precise treatment planning and fluent bidirectional feedback between the surgeon and the orthodontist are mandatory.

Evidence level 2b: Choi *et al*[77] in 2013, performed a prospective study to determine intervention outcomes in 24 standard and 32 surgery-first approaches for patients with skeletal class Ⅲ dentofacial deformity. In the surgery-first approach, a dental model was created and a novel preoperative orthodontic simulation of the standard presurgical orthodontic treatment was performed to determine the final occlusion between the maxilla and mandible. Changes in cephalometric landmarks were compared between the standard and surgery-first groups in the preoperative, immediate postoperative, and postoperative periods. The researchers found that a surgery-first approach without presurgical orthodontic treatment is possible and can give similar results to standard orthognathic surgery.

Corticision

"Corticision" was introduced as a supplemental dentoalveolar surgery in orthodontic therapy to achieve accelerated tooth movement with minimal surgical intervention. In this technique, a reinforced scalpel is used as a thin chisel to separate the interproximal cortices transmucosally without reflecting a flap[78].

In Young-Guk Park's[79] lecture (level 5), he described the procedure in detail: (1) in previously anesthetized subjects the surgical blade is inserted interproximally and parallel to the occlusal plane 5 mm apical from the tip of the papilla. The blade is tapped with a mallet to a depth of approximately 8 mm. The angle of the blade to changed to approximately 45 degrees apically and the blade is tapped to a depth of 10-12 mm. The blade is changed after four to five slices. The goal is to cut the cancellous bone between the roots to 50%-75% of the root length. To remove the blade, the blade and handle are grasped and the scalpel is worked up and down a few times before pulling the blade out. The blade is pulled rather than the handle to avoid breaking the blade. Test the mobility of the teeth by forcibly trying to move them slightly. Apply orthodontic forces immediately. The patient is seen every two weeks and the teeth are forcibly mobilizing to induce minor trauma to extend the effect; and (2) according to Park, this is a minimally invasion technique to induce accelerated tooth movement by stimulating osteoblasts and bending alveolar bone that has been surgically separated.

According to Bondemark[80], there is no movement acceleration technique that provides strong evidence (at least two studies with high value of evidence: Randomized clinical study or a prospective study with a well-defined control group). Accordingly, it is necessary to have an alternative to classify the limited literature available on this particular subject, and randomized clinical trials on this topic must be developed.

Multiple reports on orthodontic acceleration in humans have been observed using an alternative evidence level scale and this a simple and accurate way of determining which technique is most effective. The highest level of evidence for a specific procedure to accelerate orthodontic dental movement up to October 2013, is for surgery first, followed by low level laser application and corticotomy located on level 2, recommendation grade b from this proposed scientific evidence scale. Nonetheless, there is a necessity for more studies with a higher level of evidence,considering that this teraphies are located on a moderate level of evidence.

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P- Reviewer: Ferreira MM, Kanzaki H **S- Editor**: Wen LL
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