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Advances in Orthodontic Treatment

A Peer-Reviewed Publication

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Educational Objectives

The overall goal of this article is to provide dental professionals with information on orthodontic treatment options.

Upon completion of this course, the participant will be able to do the following:

1. Know the reasons patients request orthodontic treatment, as well as the reasons they may reject orthodontic treatment
2. Know the biomechanics involved in orthodontic tooth movement
3. Know the factors that can increase the duration of orthodontic treatment
4. Understand the role static and cyclic forces play in biomechanics and the potential duration of orthodontic treatment

Abstract

Functionality and aesthetics are key considerations in patients requesting, and orthodontists recommending, orthodontic treatment. However, patients may elect to forego orthodontic treatment due to the cost and the duration of treatment. Orthodontic treatment can be provided using removable or fixed orthodontic appliances (FOAs), and current options offer improved aesthetics compared to earlier generation appliances. Many methods have been explored and developed to reduce the duration of treatment. Most recently, a device has been developed that utilizes the concept of cyclic force application to reduce the duration of orthodontic treatment.

Introduction

Orthodontic treatment is requested and recommended for functionality and aesthetics. Patients seek orthodontic treatment primarily for aesthetic reasons. Orthodontists typically recommend orthodontic treatment to patients for function. The number of orthodontic cases has continued to grow over time. Between 1990 and 1999, the number of orthodontic cases annually more than doubled, from approximately 25.8 million cases to more than 61 million cases. The majority of cases in 1999 were for comprehensive therapy – around 48 million, with 81.5% of these in the 10–19 age group and just over 14% in adults age 20 and over.¹ The number of adult cases has increased in the last decade as the importance of aesthetics has increased and affluence has led to an increased demand. Treated cases by age and type can be found in Table 1.

Table 1. Orthodontic cases

	Total	Under age 10	Ages 10 - 19	Age 20 and above
Comprehensive orthodontics	48,184,000	4.40%	81.50%	14.10%
Interceptive orthodontics	6,412,200	53%	46.60%	0.40%
Limited orthodontics	7,118,200	19.40%	56.90%	23.70%

Adapted from: American Dental Association. 1999 Survey of dental services rendered

Patients may elect to forego orthodontic treatment due to the cost of treatment, the duration of treatment – most cases traditionally take 1.5–2.5 years to complete – or due to the appearance of orthodontic appliances (depending on the type used). In addition, some patients have difficulty wearing orthodontic appliances, which can result in patients starting but not completing orthodontic treatment. Dental professionals may reject patients for orthodontic treatment due to an assessment that the patient will be noncompliant with treatment or noncompliant with oral hygiene requirements during orthodontic treatment. The patient’s treatment may also be discontinued due to noncompliance. The duration of treatment, oral hygiene requirements and appearance during treatment vary depending on the type of orthodontic treatment and appliances used.

Table 2. Rejection of treatment

Patients
Duration of treatment
Poor aesthetics during treatment
Difficulty wearing an appliance
Cost
Dental Professional
Poor compliance with use (removable)
Poor compliance with adjustment appointments
Poor oral hygiene
Unrealistic patient expectations

Orthodontic Appliances

Orthodontic treatment can be provided using removable or fixed orthodontic appliances (FOAs). Removable appliances include acrylic plates with clasps and springs variously positioned depending on the treatment needs. Simple orthodontic cases can be successfully treated using this type of appliance, which also relies on the patient wearing the appliance as instructed. Since the appliance is removable, patients may be noncompliant and leave the appliance out for extended periods of time, which can result in slower treatment or “reversal” of tooth movements. Other removable appliances include those designed for specific tooth movements, such as the Schwartz appliance. Removable appliances offer the advantage of being able to be removed for oral hygiene procedures, simplifying oral home care, but are subject to noncompliance and lack of use by patients.

A more recent removable option is the use of clear resin full coverage “invisible” orthodontic appliances (Invisalign, Align Technology). These have increased adult orthodontic case acceptance and adult requests for orthodontia due to their acceptable aesthetics. Clear, full-coverage, removable resin appliances are not indicated for all types of cases, and three-axis tooth movement is better controlled using standard fixed appliances; they can be used stand-alone or after use of a fixed orthodontic appliance. Clear aligners have been found

to be more comfortable for the patient and to result in less periodontal inflammation than fixed appliances (noting that such periodontal inflammation has been found to resolve following removal of fixed appliances).^{2,3} However, Invisalign and similar products only address crowding up to a few millimeters and cannot address most cases with bicuspid extractions. Accordingly, Invisalign and similar products only serve a fraction of the orthodontic patient population.

Figure 1. Clear, full-coverage aligner



Functional appliances are used to influence and alter the positioning of the patient's hard tissues (teeth, alveolar bone and jaw positions) by altering the patient's function. These may be fixed or removable. Examples of functional appliances include the Herbst, which is fixed and therefore does not require patient compliance for wear; the bionator and Frankel appliances, which are removable.

Figure 2. Functional appliance (Herbst)



Fixed orthodontic appliances are used for the majority of orthodontic cases. Modern fixed orthodontic appliances have their genesis in Angle's ribbon arch technique, which was introduced in the early 20th century. The ribbon arch technique utilized a curved archwire with friction sleeve nuts and threaded ends, and bands with lockpins cemented on the teeth. This appliance was the first that could achieve controlled three-axis tooth movement.⁴ The ribbon arch technique was subsequently replaced by the Edgewise technique in the 1920s. Over time, nickel-silver bands and archwires superseded gold-platinum, and were later replaced by stainless

steel bands and archwires. The latest-generation fixed orthodontic appliances utilize either clear or metal brackets that are bonded onto the buccal/facial surfaces of the teeth with the archwire threaded through attachments on the brackets. The ability to successfully bond orthodontic brackets to teeth has removed the need to utilize banding encircling the teeth, thereby improving aesthetics and reducing discomfort, as well as reducing the impact of orthodontic treatment on oral hygiene requirements and difficulties. In addition, the use of clear resin bonded brackets has substantially improved the aesthetics during treatment with FOAs. Currently available appliances frequently incorporate the use of elastics into forces applied during therapy, and nickel-titanium is utilized for the archwires and other wire/spring components. Variations include lingual/palatal appliances designed to achieve tooth movement with improved aesthetics during treatment, and the use of self-ligating brackets, which have simplified the process of attaching archwires to brackets.

Regardless of the design, each generation of orthodontic appliance to date has utilized static force to move the teeth, i.e., force that is applied continually between visits and is only altered as a result of adjustments during orthodontic recall visits.

Mechanism of Action of Orthodontic Appliances (Biomechanics)

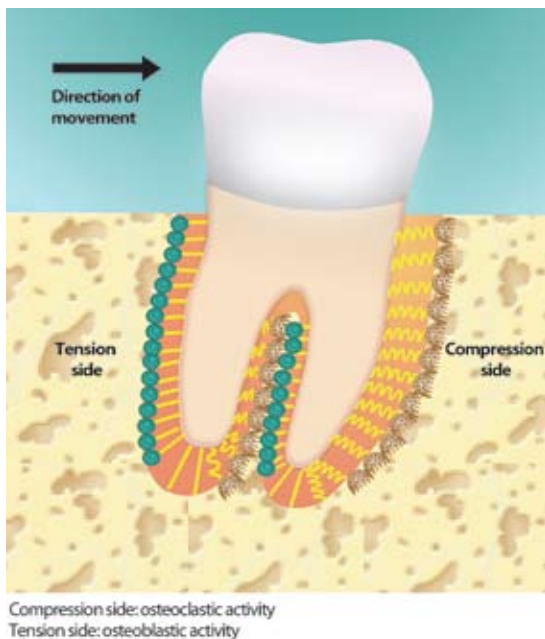
Bone is known to adapt to mechanical forces, including weight-bearing loads and orthodontic (therapeutic) forces, thereby biologically balancing the load-bearing capacity of bone with the mechanical stress to which it is subjected.^{5,6,7} The opposite is also seen with disuse atrophy, when loss of bone or muscle mass occurs with disuse, such as during immobilization.⁸ The application of mechanical force is the premise for orthodontic tooth movement. When a mesial force is placed on a tooth, bone is resorbed on the mesial surface (compression side) and laid down on its distal (tension side) surface.

Orthodontic appliances have relied on static force to induce bone remodeling and tooth movement, with the duration of treatment depending on the rate of bone remodeling. As force is applied to the tooth, micromovement results in it flexing, and the periodontal ligament and bone on that aspect of the root undergo remodeling, with resorption of the bone. The alveolar bone on the opposite side undergoes bone formation. This combination represents the bone remodeling process during orthodontic treatment. The osteoclasts are responsible for bone resorption, which begins with the attachment of these cells to the bone surface, after which acid dissolution of the hydroxyapatite occurs and is followed by destruction of the bone's organic matrix. The osteoblasts are the cells that develop bone matrix and maintain the bone's structure.⁹ The mechanical forces during orthodontic treatment result in tissue-borne and cell-borne mechanical stresses, which in turn induce interstitial fluid flow. The anabolic or catabolic effects of this fluid flow rely upon deformation of extracellular

matrix molecules, transmembrane channels, the cytoskeleton and intranuclear structures.¹⁰

Chemical mediators are involved in the bone remodeling process associated with orthodontic movement, which is an inflammatory process. This involves interaction between the osteoclasts and osteoblasts. The osteoblasts produce Receptor activator of nuclear factor kappa B ligand (RANKL) in response to the release of prostaglandin (PGE₂) from osteoclasts. In turn, this ligand expresses osteoprotegerin (OPG), which suppresses osteoclast formation.^{11,12} Compressive forces on periodontal ligament (PDL) cells induce RANKL expression with few changes in OPG expression. In contrast, tensile forces on PDL cells cause the up-regulation of both OPG and RANKL expression. These differences may explain why the compression side of orthodontic tooth movement is associated with an increase in bone resorption.^{13,14,15,16}

Figure 3. Orthodontic tooth movement



Considerations in the Duration of Orthodontic Treatment

The duration of treatment is influenced by the complexity of the case, the amount of tooth movement required, and the type of appliance used. For similar malocclusion cases, noncompliant patients are likely to have a longer duration of treatment than compliant patients; it is also known that patients who are noncompliant with oral hygiene are more likely to be the patients who attend recall adjustment appointments with irregularity.

Treatment duration is also influenced by the amount and type of force applied to the teeth as a function of bone remodeling dynamics. It has been shown that dynamic forces, rather than static forces, result in increased bone formation and the anabolic effects of mechanical loading.^{17,18} Furthermore, the response to a long-duration static load decreases

over time, hypothesized to be a result of the bone becoming desensitized to it.^{19,20} It is known that bone responds to a few cycles of large strain, however, it also responds to low magnitude strain with many cycles or high-frequency vibrations, resulting in an increase in bone density.^{21,22} With static force, a balance has been required between the amount of force applied and the speed of tooth movement. Too little force can substantially increase the duration of treatment. Applying too much force may result in more rapid tooth movement, but with deleterious effects that include root resorption and the potential for increased discomfort during treatment. Root resorption is a natural process that occurs during the exfoliation of the primary dentition. In the permanent dentition, root resorption can be associated with previous endodontic therapy, trauma, inappropriate use of internal bleaching agents (i.e., inappropriate use of a chemical agent and/or lack of a coronal seal for the root canal), or inappropriate orthodontic forces. The act of intruding teeth has been shown to increase the risk of root resorption compared to extruding teeth. It has also been suggested that the use of anti-inflammatories may inhibit orthodontic root resorption; their use also reduces orthodontic tooth movement by reducing inflammation.^{23,24,25}

The size, amount, and type of orthodontic force applied, as well as the type of tooth movement being effected all influence external root resorption, as do individual risk factors that probably include genetic predisposition.^{26,27}

Table 3. Factors in treatment duration

Complexity of the case
Amount of tooth movement required
Type of appliance used
Compliance
Oral hygiene
Amount of force
Type of force
Medication use – anti-inflammatories

Reducing the Duration of Treatment

The lengthy duration of orthodontic treatment can deter patients from receiving treatment and can result in increased noncompliance or in patients aborting treatment.²⁸ Lengthy orthodontic treatment is more likely to elicit aberrant root resorption. Many methods have been explored to reduce the duration of treatment. Treatment planning has improved and become more sophisticated, with staging of tooth movements based on linear and rotational velocities, which has enabled simultaneous movement of all teeth, rather than a few at a time. This also results in more space between the teeth during movement, rather than relying on interproximal reduction.²⁹ In vivo experiments utilizing chemical mediators associated

with orthodontic tooth movement have also shown that the introduction of exogenous OPG reduces the rate of orthodontic movement, while RANKL increases its rate. This approach may hold promise for the future in the regulation of the rate of tooth movement.^{30,31,32} However, application of chemical or biological mediators may have untoward side effects locally in the oral cavity and/or systemically, affecting other organs. The development of novel chemical or biological mediators typically takes years if not decades, and requires excessively large resources. Surgical orthodontics and temporary anchorage devices have all been introduced that can also increase the speed of treatment and reduce its duration.

Temporary anchorage devices

The use of temporary anchorage devices (TADs), also known as mini-implants or mini orthodontic screws, can speed up orthodontic treatment in some cases.^{33,34} TADs produce absolute skeletal anchorage and have been used successfully to treat cases of varying degrees of complexity. Care is required during their placement to ensure they are correctly positioned and to avoid iatrogenic damage associated with impingement of a TAD on a nerve, root surface or the periodontal ligament. Extra care is also required by the patient to maintain oral hygiene around the TAD to avoid infection at the site of placement.^{35,36}

Figure 4. Temporary anchorage device and FOA



Courtesy of RMO

Surgical orthodontics

Surgical orthodontics has been introduced to increase both the amount and speed of tooth movement. One technique, Wilkodontics, utilizes a combination of orthodontic treatment and alveolar ridge augmentation. Selective partial decortication of the cortical plates has been found to increase the speed of tooth movement during orthodontic therapy compared to traditional FOAs. After placement of the FOA, decortication can be performed several days later, with full-thickness flaps used at the surgical site. This can be accompanied by alveolar bone grafting/augmentation to increase the thickness of the bone plate at sites where thicker bone will be desirable. Cases performed where adjustments were made every two weeks for the application of static forces have shown that this method increases the rate of tooth movement and results in a thick-

ened cortical plate, with the alveolar crest height maintained during treatment. In addition, no significant root resorption was found, hypothesized to be due to demineralization/remineralization of the bone rather than resorption and accretion of bone found with typical orthodontic tooth movement.^{37,38} Partial decortication has been found to increase both anabolic and catabolic effects in laboratory studies. The catabolic effects were found to increase osteoclast activity and reduce bone surface, while the anabolic effects increased bone formation. Increased bone turnover was found, localized to the area adjacent to the decortication.³⁹

Table 4. Methods of reducing treatment duration

Staging of tooth movements (linear and rotational velocities)
Temporary anchorage devices
Decortication
Cyclic force application
Use of chemical mediators (experimental)

The Application of Cyclic Force

Research has demonstrated that the use of cyclic forces increases the rate of bone remodeling compared to static forces.^{40,41,42} In a pilot study in one human subject, a pulsating force device was investigated and was found to enhance and speed tooth movement, although it was never introduced commercially; both the rate of movement and the total amount of movement were enhanced.⁴³

Cyclic forces have been found to accelerate the rate of bone remodeling to levels far greater than static forces or intermittent forces.^{41,42,44,45,46,47} While similar in their nonconstant nature, cyclic forces – sometimes referred to as pulsatile forces – are different than intermittent forces that are applied for some duration of time, removed, and then reapplied.⁴⁸ A static force occurs once and affects cells once; an intermittent force is still a static force, the only difference is that it is introduced episodically. In contrast, cyclic forces are oscillatory in nature and change magnitude rapidly and repeatedly, affecting the cells with each oscillation of force magnitude.^{48,49} The frequency of cyclic forces is never zero. Force frequency is a concept of critical importance, but has rarely been considered in the field of orthodontics and dentofacial orthopedics until recent years.

Cyclic forces cause deformation by changing a structure's length multiple times, whereas intermittent and static forces can only do so once per application. At force frequencies that are greater than zero, cells are impacted multiple times. Frequencies of interest for orthodontic application range from several hertz (Hz.) up to 100 Hz. or more. Cyclic forces impact tissue structures and cells multiple times, and this seemingly subtle difference has been shown to lead to dramatic differences in biological response in both orofacial and long bones.^{41,42,47,49,50} Multiple cycles of change in force mag-

nitude, or cyclic forces, are significant because cells respond more readily to rapid oscillation in force magnitude than to constant force.⁵⁰ A force propagating through a biological tissue, such as alveolar bone and the periodontal ligament, is transduced as a tissue-borne and cell-borne mechanical stress that in turn induces interstitial flow.⁵¹ Although fluid flow is a current focus of the mechanotransduction pathways, its anabolic and catabolic effects rely upon deformation of extracellular matrix molecules, transmembrane channels, the cytoskeleton and intranuclear structures.^{10,50,51} Cells are known to respond more readily to rapid oscillation in force magnitude (i.e., to cyclic forces) than to constant forces.⁵¹

Animal studies using cyclic forces of 0.3–5 newtons (N) have demonstrated increased bone remodeling, and the delivery of cyclic forces by a vibrational device applied to molar teeth in the presence of standard static forces from an orthodontic spring resulted in a significant increase in tooth movement compared to no adjunctive device use. There was also a trend towards less root resorption when cyclic forces were applied.^{46,52,53,54}

Cyclic forces have been used for other parts of the body, such as the Juvent system that is used to counteract lost bone and muscle.⁵⁵ A second device using cyclic forces was introduced to relieve the discomfort associated with orthodontic adjustments and was found to be safe and effective.⁵⁶ Recently, a new device has been introduced (AcceleDent, OrthoAccel Technologies) that utilizes cyclic forces to reduce the duration of orthodontic treatment. The cyclic forces utilized are lower than for the pre-existing device used to relieve discomfort.

AcceleDent Device

The AcceleDent device uses the application of cyclic forces to move teeth in bone faster through accelerated bone remodeling.

Figure 5. AcceleDent device



One portion of the device is a mouthpiece similar to a sports mouthpiece, which the patient bites onto during use. The mouthpiece portion is connected to another piece that stays outside the mouth; this portion (activator) houses the components that provide the cyclic forces (vibration). The activator includes a battery, motor, rotating weights and micro-processor for storing usage data. The patient connects the mouthpiece to the activator and uses the device once daily for 20 minutes. The applied force from the device is at 0.2 N (20 grams). This low force is intended to be barely noticeable and not uncomfortable. The device can be used with all FOAs as well as clear resin aligners (Invisalign). The activator is placed in a docking station between uses to both recharge the activator and show compliance data.

Clinical Study

A pilot clinical study was conducted with 17 subjects, 14 of whom completed the study. Subjects with a Class I malocclusion and at least 6 mm of lower anterior crowding were provided with the device and instructed to use it for 20 minutes daily for six months during orthodontic treatment. Other selection criteria for the study included estimated level of compliance with use of the device in accordance with the instructions and good oral hygiene. Several subjects also required extractions and space closure.

Although compliance varied from patient to patient, patients reported using the device about 80% of the time, while the device microcomputer documented a 67% usage rate. Patients reported no adverse events during the study. Most patients reported watching television, listening to music, or playing video games while using the device. The most common word patients used to describe their device use was easy.

A cone beam device (Galileos, Sirona) was utilized to accurately measure tooth roots and to estimate any resulting root resorption, with imaging in all three planes (sagittal, axial and coronal views). The study was designed to determine if any root resorption greater than 0.5 mm occurred, or if there were alterations in root lengths. At the conclusion of the study, it was found that the differences in mean root lengths, with measurements made to the mesial buccal roots of all teeth except second and third molars, ranged from -0.127 mm to -0.416 mm in both arches. These differences were not statistically significant, and no significant differences were noted between anterior and posterior teeth. It should be noted that 0.5 mm is well below the levels of 2 mm, or one-third of the root length, considered to be clinically significant by researchers.^{57,58}

The study measured distances between teeth using a digital caliper. The overall distance in millimeters between the front five teeth, both upper and lower, was calculated during the alignment phase. The gap between teeth due to extractions was measured directly. The overall movement rate during the study was 0.526 mm per week. It was found that this device speeds up orthodontic movement without resulting in root resorption.

This device increases the rate of orthodontic tooth movement and can be used with either FOAs or clear aligners, offering flexibility. This is useful given the mix of orthodontic therapies available and particularly since some patients have combination therapy utilizing both FOAs and clear aligner therapy. Short-term daily use for 20 minutes is an advantage for patients.

Summary

Orthodontic treatment is designed to result in improved aesthetics and/or function of the dentition and the face. Patients desire orthodontic treatment that is of short duration, effective and that does not negatively impact their appearance during treatment. The introduction first of clear brackets for fixed orthodontic appliances has improved aesthetics during treatment.

A number of methods have been introduced to help reduce the duration of treatment. Surgical corticotomies and temporary anchorage devices have been advocated for shorter-duration treatment. Most recently, a device has been developed that utilizes the concept of cyclic force application to reduce treatment time by accelerating bone remodeling.

Reducing the duration of treatment with effective and safe techniques, and improving aesthetics during treatment, increases the acceptability of orthodontic treatment for patients. The concept of the use of static forces in orthodontics has not been challenged in more than a century of clinical practice. New technologies related to the biological impact of force frequencies could represent a paradigm shift in orthodontics.

Glossary of Terms

Anabolic:

The effect of promoting metabolism for the buildup of a tissue such as bone or muscle

Catabolic:

The metabolic breakdown of tissues, such as bone or muscle, or complex molecules

Cyclic forces:

Forces with rapidly varying magnitudes during the period of application

Decortication:

The removal of the outer layer of a structure (e.g., bone)

Disuse atrophy:

The wasting of tissues (typically bone and muscle) due to lack of use

Hertz (Hz.):

A unit of frequency defined as the number of complete cycles per second. It is the basic unit of frequency in the International System of Units (SI), and is used worldwide in both general-purpose and scientific contexts. Hertz can be used to measure any periodic event.

Intermittent forces:

Static forces that are applied for a time, removed, and then reapplied

Micromovements:

Microscopic movements such as occur in teeth during orthodontic treatment

Static forces: Forces that are applied once at a constant pressure

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Author Profile

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Dr. Mao is currently Professor and Director of the Tissue Engineering and Regenerative Medicine Laboratory at Columbia University. Dr. Mao has published over 100 scientific papers and book chapters in the area of tissue engineering, stem cells and regenerative medicine. He currently serves on the editorial board of several scientific journals including *Tissue Engineering*, *Journal of Biomedical Material Research*, *International Journal of Oral and Maxillofacial Surgery*, and *Journal of Dental Research*, and has served as an Associate Editor of *Stem Cells and Development*, as well as on the

editorial board of *Medical Engineering and Physics* and *Frontiers of Bioscience*. Dr. Mao is the editor of a new book entitled “*Translational Approaches in Tissue Engineering and Regenerative Medicine*.” Dr. Mao is also the editor of an upcoming textbook entitled “*Principles of Craniofacial Growth and Development*.” Dr. Mao is currently a standing member of the Musculoskeletal Tissue Engineering Study Section of the NIH and serves on a number of review panels for NIH, NSF, US Army as well as many other grant review panels in over 18 different countries. Dr. Mao has been invited to give lectures at over 130 national and international conferences. He has also organized and chaired a number of scientific conferences including NIH-sponsored Stem Cells and Tissue Engineering Conference. Dr. Mao’s laboratory is currently funded by several research grants from the National Institutes of Health and also from industry. Dr. Mao is a consultant to Tissue Engineering and Regenerative Medicine Centers in the United States and overseas.

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Dr. Kau completed his dental training at the Faculty of Dentistry at the National University of Singapore and his orthodontic specialty and academic training at the Cardiff University in Wales, UK. Dr. Kau is an active researcher with a keen interest in three-dimensional research. He is an invited speaker on this topic and has shared his work on the international stage that includes North America, Western and Central Europe, the Baltic States, Hungary and the Far East. He actively contributes and publishes in the orthodontic literature and currently has over 150 publications and conference papers. His other research interests include multi-centre randomized control trials in orthodontics and the clinical management of hypodontia. Dr. Kau also serves on the international educational level and is on the Panel of Examiners for the Royal College of Surgeons in Edinburgh and an international examiner for the College in Cairo, Egypt. Additionally, he is on the editorial review board for the *American Journal of Orthodontics and Dento-facial Orthopaedics* and ad hoc reviewer for a number of other journals which include the *Journal of Orthodontics*, *Angle Orthodontist*, *Cleft Lip and Palate Journal*, *International Journal of Computer Assisted Radiology and Surgery* and *Evidence Based Dentistry Journal*.

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Questions

- The majority of orthodontic cases in 1999 were for comprehensive therapy, with 81.5% of these in the 10–19 age group.
 - True
 - False
- Patients may elect to forego orthodontic treatment due to the _____.
 - cost of treatment
 - duration of treatment
 - rapid results achieved
 - a and b
- Dental professionals may reject patients for orthodontic treatment due to an assessment that the patient will be noncompliant with treatment or non-compliant with oral hygiene requirements during orthodontic treatment.
 - True
 - False
- Simple orthodontic cases can only be successfully treated with fixed orthodontic appliances.
 - True
 - False
- Removable appliances offer the advantage of _____.
 - being able to be removed for oral hygiene procedures
 - simplifying compliance
 - simplifying oral home care
 - a and c
- Clear, full-coverage, removable resin appliances are not indicated for all types of cases.
 - True
 - False
- The ability to successfully bond orthodontic brackets to teeth has _____.
 - removed the need to utilize banding
 - improved aesthetics during treatment
 - reduced discomfort for patients
 - all of the above
- The application of _____ force is the premise for orthodontic tooth movement.
 - electrical
 - chemical
 - mechanical
 - none of the above
- Orthodontic treatment duration is influenced by _____.
 - the amount and type of force applied to the teeth
 - the complexity of the case
 - the type of appliance used
 - all of the above
- Bone is known to adapt to mechanical forces, including weight-bearing loads and orthodontic (therapeutic) forces.
 - True
 - False
- In the permanent dentition, root resorption can be associated with _____.
 - trauma
 - inappropriate orthodontic forces
 - inappropriate use of internal bleaching agents
 - all of the above
- Bone responds to low magnitude strain with many cycles or high-frequency vibrations, resulting in an increase in bone density.
 - True
 - False
- The use of anti-inflammatories may reduce orthodontic tooth movement.
 - True
 - False
- The mechanical forces during orthodontic treatment result in _____.
 - tissue-borne mechanical stresses
 - cell-borne mechanical stresses
 - the induction of interstitial fluid flow
 - all of the above
- Lengthy orthodontic treatment is more likely to elicit aberrant root resorption.
 - True
 - False
- Osteoclasts develop bone matrix and maintain the bone's structure.
 - True
 - False
- The bone remodeling process associated with orthodontic movement is an inflammatory process.
 - True
 - False
- The response of bone to a long-duration static load _____.
 - decreases over time
 - increases over time
 - remains the same over time
 - none of the above
- The staging of orthodontic tooth movements based on linear and rotational velocities _____.
 - has enabled simultaneous movement of all teeth
 - results in more space between the teeth during movement
 - reduces the duration of treatment
 - all of the above
- Removable appliances can be successfully used for all orthodontic cases.
 - True
 - False
- _____ may speed up orthodontic treatment.
 - Molecular devices
 - Permanent anchorage devices
 - Surgical orthodontic procedures
 - b and c
- Selective partial decortication of the cortical plates has been found to increase the speed of tooth movement during orthodontic therapy.
 - True
 - False
- Temporary anchorage devices produce relative skeletal anchorage.
 - True
 - False
- Cyclic forces _____.
 - change magnitude rapidly and repeatedly
 - affect the cells with each oscillation of force
 - are oscillatory in nature
 - all of the above
- Research has demonstrated that the use of cyclic forces increases the rate of bone remodeling compared to static forces.
 - True
 - False
- A device using cyclic forces was introduced to relieve the discomfort associated with orthodontic adjustments and was found to be safe and effective.
 - True
 - False
- An orthodontic device using cyclic forces has been found to _____.
 - speed up orthodontic movements
 - slow down orthodontic movements
 - be safe and effective
 - a and c
- Cells are known to respond more readily to rapid oscillation in force magnitude than to constant forces.
 - True
 - False
- Anabolic effects involve the metabolic breakdown of tissues, such as bone or muscle, or complex molecules.
 - True
 - False
- Reducing the duration of treatment with effective and safe techniques, and improving aesthetics during treatment, increases the acceptability of orthodontic treatment for patients.
 - True
 - False

Advances in Orthodontic Treatment

Name: _____ Title: _____ Specialty: _____

Address: _____ E-mail: _____

City: _____ State: _____ ZIP: _____ Country: _____

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Requirements for successful completion of the course and to obtain dental continuing education credits: 1) Read the entire course. 2) Complete all information above. 3) Complete answer sheets in either pen or pencil. 4) Mark only one answer for each question. 5) A score of 70% on this test will earn you 4 CE credits. 6) Complete the Course Evaluation below. 7) Make check payable to PennWell Corp.

Educational Objectives

1. Know the reasons patients request orthodontic treatment, as well as the reasons they may reject orthodontic treatment
2. Know the biomechanics involved in orthodontic tooth movement
3. Know the factors that can increase the duration of orthodontic treatment
4. Understand the role static and cyclic forces play in biomechanics and the potential duration of orthodontic treatment

Course Evaluation

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

1. Were the individual course objectives met?	Objective #1: Yes	No	Objective #3: Yes	No		
	Objective #2: Yes	No	Objective #4: Yes	No		
2. To what extent were the course objectives accomplished overall?	5	4	3	2	1	0
3. Please rate your personal mastery of the course objectives.	5	4	3	2	1	0
4. How would you rate the objectives and educational methods?	5	4	3	2	1	0
5. How do you rate the author's grasp of the topic?	5	4	3	2	1	0
6. Please rate the instructor's effectiveness.	5	4	3	2	1	0
7. Was the overall administration of the course effective?	5	4	3	2	1	0
8. Do you feel that the references were adequate?		Yes	No			
9. Would you participate in a similar program on a different topic?		Yes	No			
10. If any of the continuing education questions were unclear or ambiguous, please list them.	_____					

11. Was there any subject matter you found confusing? Please describe.

12. What additional continuing dental education topics would you like to see?

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| 14. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D | 29. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D |
| 15. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D | 30. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D |

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