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Chih-Wei Wang
Orthodontic and Dental Department, Chang Bing Show Chwan Memorial Hospital, Changhwa, Taiwan

Kai-Long Wang
Orthodontic and Dental Department, Chang Bing Show Chwan Memorial Hospital, Changhwa, Taiwan

Kwok-Hing Ho
Orthodontic Department, Show Chwan Memorial Hospital, Changhwa, Taiwan

Shun-Chu Hsieh
Orthodontic and Dental Department, Chang Bing Show Chwan Memorial Hospital, Changhwa, Taiwan

Heng-Ming Chang
Orthodontic and Dental Department, Chang Bing Show Chwan Memorial Hospital, Changhwa, Taiwan, markortho@gmail.com

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Review Article

Dental Pulp Response to Orthodontic Tooth Movement

Chih-Wei Wang,[1] Kai-Long Wang,[1] Kwok-Hing Ho,[2] Shun-Chu Hsieh,[1] Heng-Ming Chang[1]

[1]Orthodontic and Dental Department, Chang Bing Show Chwan Memorial Hospital, Changhwa, Taiwan

[2]Orthodontic Department, Show Chwan Memorial Hospital, Changhwa, Taiwan

Pulp vitality may occasionally change while tooth experiencing orthodontic movement, and orthodontists are the particular group who concern this phenomenon if it happens. The respiration rate of dental pulp will be depressed inevitably in short term when tooth is subject to orthodontic force. If force level is extreme, circulatory interruption can occur and further induce pulp necrosis. When orthodontic movement on pulpal-compromised teeth (e.g. teeth with trauma history or large restorations) is required, the pulp response to orthodontic force should be monitored. This article provides an overall review on the pulpal reactions during orthodontic movement and dental movement on teeth with previous endodontic treatment. ***(Taiwanese Journal of Orthodontics. 29(4): 204-212, 2017)***

Keywords: pulp response; orthodontic tooth movement; pulp vitality; endodontically-treated teeth

INTRODUCTION

Orthodontic tooth movement occurs by remodeling changes in the periodontium, including periodontal ligament (PDL), cementum and alveolar bone. The force applied within the periodontium will also produce mechanical damage and inflammatory over the pulp-dentine complex. Dental pulp is composed of fibroblasts, odontoblast, undifferentiated mesenchymal cells, capillaries and sensory nerve fibers. The primary function of the dental pulp is to form dentin. Other functions, such as nutrition, sensory and protection are also important. Pulp tissue may also regulate pulp blood flow and dentinal fluid dynamics. These mechanisms provide reflexes to preserve dental tissues and promote wound healing.[1]

Orthodontic tooth movement seems to be relatively safe on pulpal health during regular treatment, but pulp tissue may turn necrotic occasionally. This particularly happened on pulpal-compromised teeth, e.g. teeth with previous trauma history or large restorations etc. It is very difficult to have proper diagnosis and prevention in advance, so, therefore, we hope to provide an overall understanding on the pulpal response to the orthodontic treatment. This article will also address the reactions of pulpal-compromised teeth during orthodontic movement and the dental movement of previous endodontic-treated teeth.

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Reprints and correspondence to: Dr. Heng-Ming Chang, Director, Department of Orthodontics, Chang Bing Show Chwan Memorial Hospital, Changhua, Taiwan
No.6, Lugong Rd., Lugang Township, Changhua County 505, Taiwan
Tel: 886-4-7812868 Fax: 886-4-7812869 E-mail: markortho@gmail.com

THE INFLUENCE OF ORTHODONTIC FORCES ON THE DENTAL PULP

Pulpal Reactions

Application of orthodontic forces to teeth will induce molecular changes on the cells within the periodontium. The peripheral sensory nerve system contributes to the development of acute and chronic inflammatory processes through local release of neuropeptides. When orthodontic appliance is activated, the transient inflammatory response may cause discomfort to patient for few days. The response initiates from acute inflammatory, which includes vasodilatation and leukocyte migration in the PDL.[2] The migratory cells will produce various local biochemical signal molecules and cytokines. After 24 to 48 hours of the force application, chronic inflammation follows and this involves fibroblasts, osteoblasts, endothelial cells, and alveolar bone marrow cells during the process. The leukocytes continue to migrate to periodontal tissues and keep modulating the remodeling process.[3]

Interestingly, there is no conclusive evidence on the relation between orthodontic force and pulp tissue in human.[4] Yet tooth movement involves cell damage, inflammation and wound healing, which may affect on the health of dental pulp. Proffit et al. has stated that light continuous force has an impact on the PDL but has little or no effect on the pulp.[5] However, pulp necrosis may occasionally be found during orthodontic treatment. This is usually related to previous dental trauma including severe periodontal injury,[6] large decay, exceeding orthodontic force or dental movement outside the trough of the alveolar process etc. These scenarios may block blood supply entering the chamber of tooth. Mostafa et al. have reported that excessive intrusive/extrusive force magnitude may disturb the circulation of dental pulp and degenerate the odontoblastic layer.[7] These factors will potentially result in pulpal necrosis.

In adolescences, the prevalence of dental pulp damage resulted from orthodontic treatment was about 2%-17% for canal obliteration and 1%-14% for pulpal necrosis.[8] Changes occurred in the pulp are considered to be reversible most of the time unless the pulp had previous damage. The degree of pulpal change may be influenced by the severity of previous violation to the pulp. Sometimes, the pulp tissue health was compromised before the application of orthodontic force. We should be very cautious of moving this type of tooth and monitoring the pulpal status throughout the whole orthodontic treatment period. Although there are very few reports on the loss of tooth vitality related to excessive orthodontic force, it is still assumed that larger orthodontic force may potentially cause pulpal changes and the consequences is much more severe.[9]

Cellular responses – Neuropeptides and Inflammatory Cytokines

Orthodontic force will change vascularity and blood flow of periodontal tissue, and this will induce the local synthesis and release of various molecules, such as neuropeptides, cytokines and growth factors etc. During developments of acute and chronic inflammatory processes, neuropeptides will be released in the pulp and periodontium tissues for vasodilatation, which will incense the vascular permeability and this is the key to bone metabolism (growth and remodeling).[10-12] The neuropeptides include substance P (SP), calcitonin gene-related peptide (CGRP), neurokinin A (NKA) and so forth. The expressions of SP, CGRP, and NKA on the inflamed dental pulp of humans are found to be significantly higher than on the normal healthy controls.[13]

SP is a sensory neuropeptide presenting in both the peripheral and central nerve systems. It is secreted by macrophages, eosinophils, lymphocytes, and dendritic cells etc. when inflammation occurs. It can induce synthesis of pro-inflammatory cytokines from pulpal fibroblast (Figure1).[14] The release of SP during inflammation can cause vasodilation and increase vascular permeability. These responds can increase blood flow to the inflammation sites.

On the other hand, CGRP is localized to small/medium sensory nerve fibers. It plays an important role on the pulp response to inflammation and wound healing (Table 1). It is also an effective vasodilator and regulates blood flow in bone and periosteum.[1] SP and CGRP can stimulate the production of interleukin (IL)-1β, IL-6, and tumor necrosis factor (TNF)-α from the fibroblasts in human dental pulp.[15]

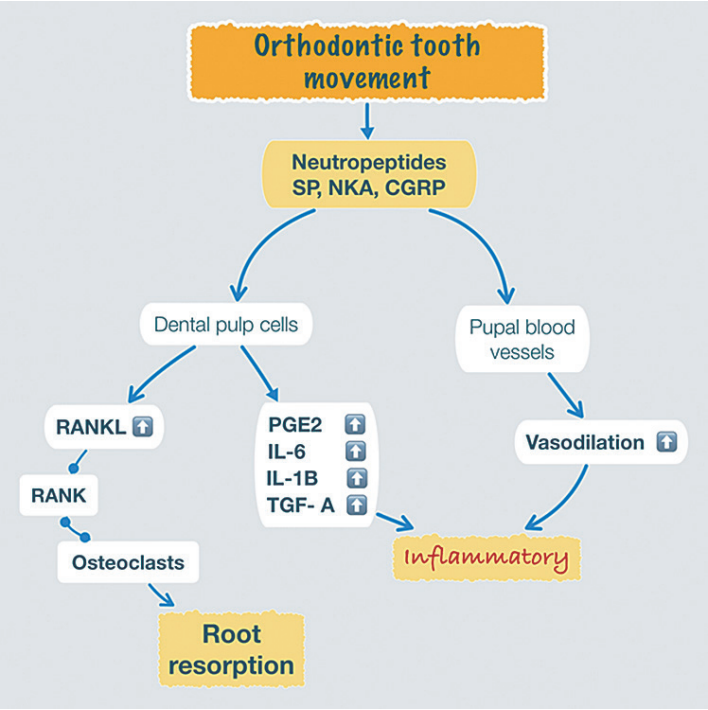

Figure 1. *Pulpal inflammatory process to orthodontic force.*
Modified from: *Yamaguchi M and Kasai K, The effects of orthodontic mechanics on the dental pulp, Seminars in Orthodontics. 2007;13: 272-280.*

Table 1*. Key effects of substance P in dental pulp.*

Healthy tissues
Maintenance of tissue homeostasis
Inflamed tissues
Vasodilatation
Histamine release
Increase in blood flow
Increase in vascular permeability
Increase in blood pressure
Synthesis of proinflammatory cytokines
Chemotaxis of inflammatory cells

Modified from: Sacerdote P and Levrini L. Peripheral mechanisms of dental pain: The role of substance P. *Mediators of Inflammation, Volume 2012.*

The bone-remodeling process includes bone formation and resorption, which can be regulated by hormones, e.g. estrogen, thyroxine, parathyroid hormone, and other cytokines etc. These cytokines directly interact with specific receptors in osteoblasts and modulate the maturation, proliferation, and differentiation of osteoclasts. The most important pathway regulating osteoclasts formation and differentiation is the pathway related to receptor activator of nuclear factor κ (RANK), receptor activator of nuclear factor kappa-B ligand (RANKL) and osteoprotegerin (OPG). RANKL is a member of tumor necrosis factor (TNF) cytokine family that binds to the RANK and functions as a key factor for osteoclast differentiation and activation. Osteoprotegerin (OPG) provides an alternative binding site for RANKL and acts as a decoy receptor by blocking RANKL binding to its cellular receptor RANK.[16]

Several studies focus on the enzyme activity of the dental pulp after orthodontic force application. Alkaline phosphatase (ALP) is a glycoprotein involved in the mineral formation processes within bone and cementum.[17] The pulpal fibroblasts and odontoblasts can synthesize and release ALP.[18] While tooth is exposed to the orthodontic force, the activity of ALP will drop.[19] On the contrary, high level of aspartate aminotransferase (AST) is presented in inflammatory pulp because it is an essential mediator in inflammatory processes. Orthodontic force increases AST activity initially, and it returns to normal values after 14 days.[20]

Vasodilatation and Angiogenic Response to Orthodontic Forces

The application of orthodontic force has a significant impact on blood supply of pulp. It decreases pulpal blood flow (PBF) temporarily during tooth movement, but it will return normal within 72 hours. The PBF can be measured by Laser Doppler flowmetry, which is recommended in most studies.[21] The reduction of PBF will decrease the oxygen supply. This will directly impact on the metabolism of the pulp tissue and increase the chance of cellular injury and apoptosis.

The change of PBF with regard to orthodontic force is associated with: (1) the size of apical foramen; (2) patient's age; (3) dentinogenic activity; and (4) magnitude and duration of the force applied.[22] The respiratory rate of pulp cells is closely related to the PBF, which determines the degree of dentinogenic activity. As patient age increases, the respiratory rate of pulp tissue becomes decreased. Besides, teeth with open or large apices will have higher activities during dental movement and lower unfavorable side effects from orthodontic treatment.[23]

Angiogenesis is the formation of new capillary structures. This process will ultimately lead to the organization of larger structures by neovascularization.[24] Angiogenesis is mainly found in the embryo developing, wound healing/ repair, tissue development/ grow, and inflammatory process. Similar mechanism is found in pulp tissue. Odontoblast progenitor cell will migration to the injury site to form new blood vessels after pulp injury. The orthodontic force also induces similar situation like vasodilatation and angiogenesis in the dental pulp.[14] Several studies have shown orthodontic force may induce the expression of various growth factors (GFs), such as epidermal growth factor (EGF), platelet derived growth factor (PDGF), vascular endothelial growth factor (VEGF), fibroblast growth factor-2 (FGF-2) and transforming growth factor beta (TGF-β) etc. These angiogenic growth factors significantly increase the number of micro-vessels during the early stage of orthodontic movement.[25] The increase of vascular volume density returned to normal values within 72 hours of force application. This has been considered insignificant regarding long-term damage to the pulp tissue.

ORTHODONTIC MOVEMENT IN ENDODONTICALLY-TREATED TEETH

In some situations, orthodontic force may apply on teeth having had or being under endodontic treatment.

Before moving these teeth, we must evaluate the conditions of tissue repair and the degree of inflammation. According to previous studies, if root canals are cleaned, shaped, and sealed properly, teeth can be moved in the same way as teeth with normal pulps.[25] Complete and intake PDL on the radiograph is another sign of success.[5]

Interestingly, several studies have shown that teeth with well endodontic treatment may have less tendencies of root resorption or remodeling than vital teeth may have during orthodontic tooth movement.[26, 27] The main theory is that the absence of pulp tissue will result in the less production of neuropeptides, such as SP, CGRP, NKA etc., which are related to the metabolisms of root resorption.[28]

Teeth without periapical lesion

In our daily practice, teeth may need endodontic treatment because of pulpitis or pulp necrosis. Proper endodontic treatment with well cleaning, shaping, and three-dimensional obturation was the first object before orthodontic movement. After well obturation, 1 month of follow-up is necessary for the exudate and the inflammatory cells to be absorbed and removed. After that, the orthodontic force can be applied and treatment can be commenced.

If tooth unfortunately requires root canal treatment during orthodontic movement, it is recommended to clean and shape the root canals thoroughly followed by calcium hydroxide dressing until the end of orthodontic treatment. This protocol reduces the risk of root resorption during tooth movement.[29] Moreover, the cavity should be sealed properly with resin or glass ionomer to prevent bacterial leakage. The canals can be obturation with GP and sealer when orthodontic tooth movement has done.[9]

Teeth with inflammatory periapical lesion

The periapical lesion or disease is associated with the microbial flora present in the canals in which the dental pulp is necrotic due to caries or dental trauma. Endodontic treatment on tooth with acute inflammatory periapical disease usually has good prognosis because there is minimal area of apical root resorption and less microbial flora around the apex. It is easier to eliminate the microbiota and to make the lesion healed.

The microbial flora persists longer within the chronic inflammatory periapical diseases, such as chronic apical periodontitis or periapical granuloma etc. This is because the bacteria are allowed to form biofilms and colonize within the dentinal tubules, isthmus, lateral canals and the external part of the apical surface. These areas are not easy to reach while mechanical instrumentation. Complete elimination of the microbial components in these cases sometimes may be difficult, and thus, healing of chronic periapical lesion cannot be assured.

Teeth with previous chronic periapical lesions but being well treated can have orthodontic treatment with no problem on repairing. Fifteen to thirty days of follow-up after endodontic treatment can allow the exudate and inflammatory infiltrate to be absorbed from the lesion.[30] Orthodontic tooth movement can be started few days after that. The main reason for the failure of healing is probably due to the limitation of endodontic treatment rather than tooth movement itself.

Aseptic pulp necrosis and dental trauma

The aseptic pulp necrosis usually occurs on previous-traumatized teeth. It is usually unnoticed until sign or symptom was reported from routine radiographic check-up or when tooth discoloration happened. The microbiota on the necrotic pulp presents less aggressiveness and the metabolic activity is lower.[30]

Previous-traumatized teeth can have successful orthodontic movement if endodontic treatment can be done properly before orthodontic treatment. The more severe the dental trauma is, the poorer the prognosis could be during the treatment.[29] Therefore, the magnitude of orthodontic force to the traumatized teeth should be reduced and routine follow-up of this tooth is necessary. In addition, the chance of extreme root resorption may largely increase on the traumatized teeth after orthodontic

Table 2. *Clinical and orthodontic protocols face dentoalveolar trauma.*

Type	Clinical findings	Radiographic	Clinical protocol	Orthodontic protocol
Concussion	Sensitivity to percussion. Without increased mobility	No abnormalities.	Monitoring of pulpal condition > 1 year.	Wait 3-5 months. Radiographic control > 1 year. Mild and intermittent forces
Subluxation	Sensitivity to percussion. Increased mobility. Bleeding from gingival crevice may be noted.	No abnormalities.	Flexible splint for 2 weeks. Monitoring of pulpal condition > 1 year.	Wait 3-5 months. Radiographic control > 1 year. Mild and intermittent forces.
Extrusion	Tooth appears elongated (out of its socket). Excessively mobile.	PDL space is widened in apically.	Reposition. Flexible splint for 2 weeks. Monitoring of pulpal condition and radiographic for 5 years.	Wait > 6 months. Radiographic control every 3 months. Mild and intermittent forces. Simplified the orthodontic treatment.
Lateral luxation	Displacement of the tooth in a direction other than axially. Immobile, and percussion gives a metallic sound. Alveolar process fracture.	PDL space is widened in an occlusal view.	Reposition. Flexible splint for 4 weeks. Monitoring of pulpal condition and radiographic for 5 years.	Wait > 6 months. Radiographic control every 3 months. Mild and intermittent forces. Simplified the orthodontic treatment.
Intrusion	Displacement of the tooth into the alveolar bone. Immobile, and percussion gives a metallic sound. Pulp necrosis is expected in fully developed roots.	PDL space may be absent. CEJ is located more apically.	Intruded ≤ 3 mm : waiting 2-4 weeks for spontaneous re-eruption. Intruded 3-7 mm, reposition surgically or orthodontically. Intruded > 7 mm, reposition surgically. Monitoring of pulpal condition and radiographic for 5 years.	After spontaneous eruption, orthodontic repositioning or surgical repositioning, wait > 6 months to start orthodontic movement. Radiographic control every 3 months. Mild and intermittent forces. Simplified the orthodontic treatment.
Avulsion	Complete displacement of the tooth out of its socket.	Tooth out of its socket	Replantation is the best choice. But the prognosis depends on : site of accident, storage conditions and extra-alveolar time. Flexible splint for up to 2 weeks. Monitoring of pulpal conditions and radiographic for 5 years. Prescription of antibiotics.	If normal periodontal conditions are observed, wait > 1 year to start the orthodontic movement. Radiographic control every 3 months throughout the treatment. Mild and intermittent forces. Simplified the orthodontic treatment.

Modified from :

(1) Naretto S. Principles in Contemporary Orthodontics. Ch10 Orthodontic Retreatment: Dental Trauma and Root Resorption Intech, 2011; P.239-241;

(2) Malmgren O and Malmgren B. Orthodontic management of the traumatized teeth. In: Andreasen, J.O., Andreasen, F.M. & Andersson, L., editors. Textbook and color atlas of traumatic injuries to the teeth. 4th ed. Oxford: Blackwell Munksgaard; 2007. pp. 699-715.

treatment.[31] Taking periapical radiographs routinely during the treatment is essential to review the progress of root resorption.

There are several types of dental trauma, and the waiting time prior to the orthodontic treatment may vary accordingly. In mild cases, such as concussion and subluxation, 3 to 5 months of waiting is sufficient for the healing of the affected periodontal tissues (Table 2).[29,32] In moderate trauma, e.g. severe subluxation, luxation, displacement and extrusion, a period of 6 months to 1 year is recommended. In the severe cases like root fracture, the follow-up time could be lengthened to 1 or 2 years for the fractured segments repair.[29,32] On avulsion and replantation teeth, at least 1 year should be followed to see if any complication such as ankylosis, inflammatory root resorption may develop.[29,30,32,33] Despite types of dental trauma, endodontic and periodontal conditions should be evaluated carefully before force application. Teeth can be moved only when the periodontal condition is healthy and routine radiographic check-up is recommended. The root outlines and the integrity of lamina dura and PDL spaces should be examined on the radiographs to see if any adverse effect happens. When severe resorption is noted, the orthodontic treatment should be interrupted until the progressive resorption ceased.

CONCLUSIONS

1. A comprehensive history of the teeth should be taken before orthodontic treatment, with specific attention to any history of dental trauma.
2. If root resorption is found on previous-traumatized tooth, there is a greater chance that orthodontic treatment will deteriorate the whole problem.
3. Teeth with complete root formation but with previous pulpal damage from trauma, caries, large restoration or periodontal disease etc. may be more susceptible to irreversible pulpal changes (including necrosis) under orthodontic movement.
4. If there is any evidence of pulpal infection prior to orthodontic treatment, appropriate endodontic management should be considered. After well endodontic treatment, 15 to 30 days of waiting is necessary for exudates to be absorbed. The orthodontic tooth movement can be commenced afterward.
5. Apical blood supply should not be occluded during orthodontic movement. Orthodontic force should be light and continuous in respect of pulp's condition and keep teeth within the physiological boundaries (i.e. not compressing the root apex against the cortical plate).

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