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Review

Biological aspects of orthodontic tooth movement: A review of literature

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ABSTRACT

This review of literature describes the cellular and molecular biology of orthodontic tooth movement, including various theories and effect of chemical mediators on tooth movement. The better understanding of the tooth movement mechanism will inspire the clinicians to design and implement effective appliances that will result in maximum benefits and minimum tissue damage to the patients. This paper also emphasizes the applied aspect of different medication and hormones, during orthodontic treatment, on the signaling molecules which produce bone remodeling.

Contents

1. Introduction

Orthodontics comprise of tooth movement in the jaw from one position to another to attain esthetics (Sabane, et al., 2016; Proffit and Fields, 2000a, 2000b; Al khateeb, et al., 1998). It has always been interesting for clinicians to understand the basic concept of tooth movement, so that the treatment time could be reduced, resulting in patient satisfaction (Kashyap, 2016). A lot of research has been done on the mechanical forces and tooth movement compared to the focus on cellular biology (Sabane, et al., 2016). The principle of tooth movement in which applied pressure results in remodeling is a microscopic fact (Kashyap, 2016). Although, there are lot of innovative mechanical devices for tooth movement but still we have not been totally successful in preventing periodontal injuries. This could be due to lack of complete cellular

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understanding (Sabane et al., 2016). The need to understand the specific remodeling pathways is essential to target those cells and achieve an impeccable prognosis (Al-Ansari et al., 2015). The advantage of understanding the remodeling pathways helps us to design a better appliance which targets the specific cell for a controlled and safe accelerated tooth movement (Al-Ansari et al., 2015; Oswal et al., 2015; Patil et al., 2012). The other advantage of knowing these cells can also help us to stimulate the body directly or indirectly to produce or activate these cells. The objective of this paper is to review the biological changes occurring at the molecular level during orthodontic tooth movement with special emphasis on chemical mediators and medication affecting the tooth movement.

2. Phases of tooth movement

Burstone in 1962 suggested three phases of tooth movement. They are:

(1) Initial phase
(2) Lag phase
(3) Post lag phase

Initial phase occurs immediately after the application of force to tooth. The movement is rapid due to the displacement of tooth in periodontal space. The time frame of the initial phase usually occurs between twenty-four hours to two days (Burstone, 1962). The movement of the tooth occurs within the bony socket. Due to the force applied on the tooth there is a compression and stretching of periodontal ligament which in turns causes extravasation of vessels, chemo-attraction of inflammatory cells and recruitment of osteoblast and osteoclast progenitors. After the initial phase, there is a lag phase in which the movement is minimal or sometimes no movement at all. The reason for this phase is the hyalinization of compressed periodontal ligament. The movement will not take place until the necrosed tissue is removed by the cells (Kashyap, 2016). In the lag phase the tooth movement stops for twenty to thirty days and during this time frame all the necrotic tissue is removed along with the resorption of adjacent bone marrow. The necrotic tissue from the compressed bone and compressed periodontal ligament sites are removed by macrophages, foreign body giant cells and osteoclast cells. The third phase is the post lag phase in which the movement of tooth gradually or suddenly increases and is usually seen after forty days after the initial force application (Krishnan and Davidovitch, 2006). It has been hypothesized that during displacement of tooth, a continuous development and removal of necrotic tissue occurs (Melsen, 1999).

3. Theories of tooth movement

The orthodontic force applied on the tooth structure results in a tooth movement by deposition and resorption of alveolar bone called as remodeling. This force is converted into biological activity, although this activity is not fully understood but three possible theories of tooth movement are advocated. They are:

(1) Bone-Bending theory
(2) Biological Electricity Theory
(3) Pressure-Tension Theory

3.1. Bone-bending theory

Farrar (1888) stated that when an orthodontic force is applied to the tooth, it is transmitted to all tissues near the area of force application. These forces bend bone, tooth and the solid structures

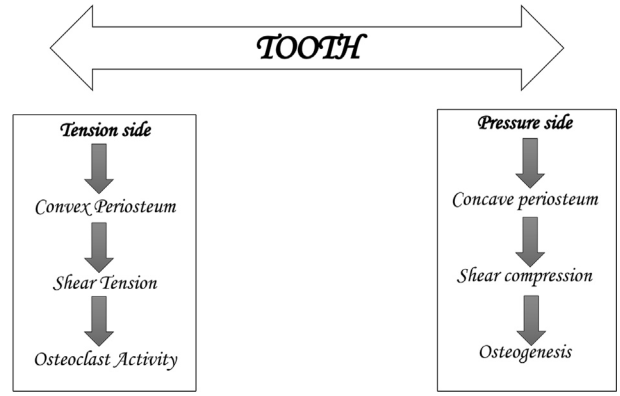

Fig. 1. Flowchart presenting the effect of applied forces on Periosteum.

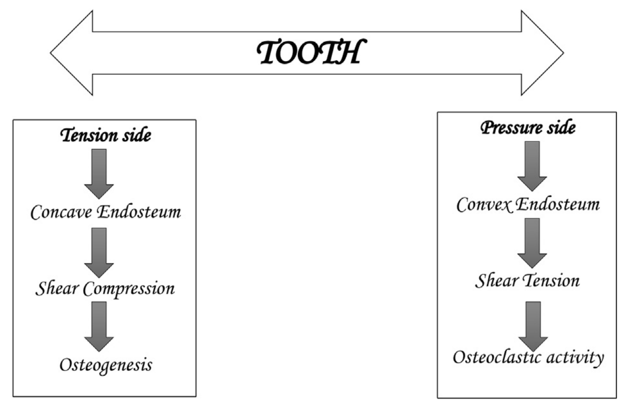

Fig. 2. Flowchart presenting the effect of applied forces on Endosteum.

of periodontal ligament (Kashyap et al., 2016). Since the bone is more elastic than the other structures it bends effortlessly and the process of tooth movement gets accelerated. This also explains the rapid tooth movement occurring at the extraction site and in pediatric patients, in which the bone is not heavily calcified and is more flexible (Baumrind, 1969). Fig. 1 and Fig. 2 presents the effect of applied forces on periosteum and endosteum respectively.

3.2. Biological electricity theory

This theory was proposed by Bassett and Becker in 1962. According to them, whenever the alveolar bone flexes or bends it releases electric signals and to some extent is responsible for tooth movement. Initially it was thought to be piezo-electric signals. The characteristic of these signals are:

(a) They have a quick decay rate which means it is initiated when the force is applied and at the same time it disappears quickly even with the force maintained.
(b) They produce equal signal on the opposite side when the force is released (Proffit et al., 1999).

After the bone bend, the ions interact with each other in the presence of the electric field causing electric signals and temperature change. A small voltage is observed called as "streaming potential". They are different from piezoelectric signals and they even can be generated by external electric field, which can modify the cellular activity. There is another type of signal present in bone that is not being stressed called as "bioelectric potential". The bone which is metabolically active shows electronegative changes that