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3D Simulation of Orthodontic Tooth Movement in the Presence of Horizontal Bone Loss

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Abstract : One of the most prevalent types of alveolar bone loss is horizontal bone loss (HBL) in which the bone height around teeth is reduced homogenously. In the presence of HBL the magnitudes of forces during orthodontic treatment should be altered according to the degree of HBL, in a way that without further bone loss, desired tooth movement can be obtained. In order to investigate the appropriate orthodontic force system in the presence of HBL, a three-dimensional numerical model capable of the simulation of orthodontic tooth movement was developed. The main goal of this research was to evaluate the effect of different degrees of HBL on a long-term orthodontic tooth movement. Moreover, the effect of different force magnitudes on orthodontic tooth movement in the presence of HBL was studied. Five three-dimensional finite element models of a maxillary lateral incisor with 0 mm, 1.5 mm, 3 mm, 4.5 mm and 6 mm of HBL were constructed. The long-term orthodontic tooth tipping movements were attained during a 4-weeks period in an iterative process through the external remodeling of the alveolar bone based on strains in periodontal ligament as the bone remodeling mechanical stimulus. To obtain long-term orthodontic tooth movement in each iteration, first the strains in periodontal ligament under a 1-N tipping force were calculated using finite element analysis. Then, bone remodeling and the subsequent tooth movement were computed in a post-processing software using a custom written program. Incisal edge, cervical, and apical area displacement in the models with different alveolar bone heights (0, 1.5, 3, 4.5, 6 mm bone loss) in response to a 1-N tipping force were calculated. Maximum tooth displacement was found to be 2.65 mm at the top of the crown of the model with a 6 mm bone loss. Minimum tooth displacement was 0.45 mm at the cervical level of the model with a normal bone support. Tooth tipping degrees of models in response to different tipping force magnitudes were also calculated for models with different degrees of HBL. Degrees of tipping tooth movement increased as force level was increased. This increase was more prominent in the models with smaller degrees of HBL. By using finite element method and bone remodeling theories, this study indicated that in the presence of HBL, under the same load, long-term orthodontic tooth movement will increase. The simulation also revealed that even though tooth movement increases with increasing the force, this increase was only prominent in the models with smaller degrees of HBL, and tooth models with greater degrees of HBL will be less affected by the magnitude of an orthodontic force. Based on our results, the applied force magnitude must be reduced in proportion of degree of HBL.

Keywords : bone remodeling, finite element method, horizontal bone loss, orthodontic tooth movement.
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