－ ORIGINAL ARTICLE －

Anchorage effect of palatal osseointegated implant on teeth with simulated bone loss: A finite element study

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骨吸収を想定した歯における矯正用パラタルインプラントの固定効果に関する有限要素法を用いた研究

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Abstract：The purpose of this study was to compare the anchorage effect of the osseointegrated implant connected on the second premolar with different alveolar bone loss using the finite element analysis. Four models with the implant and four models without the implant were constructed. Four levels of alveolar bone loss (0, 2, 4 and 6 mm) were studied. The model with the implant was consisted of two maxillary second premolars, their associated periodontal ligament and alveolar bones, palatal bone, palatal implant and transpalatal arch. The model without the implant was used to compare with the model with the implant. The horizontal force (mesial 5N, palatal 1N) was loaded at the buccal bracket of each second premolar. The stress in the periodontal ligament, implant and surrounding bone were calculated. The results showed that the palatal implant could significantly reduce von Mises stress (maximum von Mises stress was reduced from 29.63% to 44.30% with the alveolar bone loss from zero mm to six mm) and make stress even distribution in the periodontal ligament. The stress in the implant and surrounding bone was very low. These results suggested that palatal implant is a good tool to enhance the anchorage of teeth with alveolar bone loss.

抄録：本研究の目的は，第二小臼歯部の歯槽骨の吸収程度とこれに連結したインプラントによる加強固定の効果について，有限要素法を用いて検討することとした。歯槽骨の吸収の程度を４段階（０，２，４，６mm）設定し，それぞれインプラント有りと無しのモデルについて調べた。インプラントのあるモデルは，左右側の上顎第二小臼歯，歯根膜，歯槽骨，口蓋骨，パラタルインプラント，インプラントと小臼歯とを連結するパラタルバーで構成した。インプラントのないモデルは，上述のモデルにおいてインプラントを除外し，他は同じとした。水平力として，近心方向に5N と口蓋方向に 1N を両側の上顎第二小臼歯の頬側ブラケットに負荷した。この荷重を負荷した時，歯根膜，インプラントとその周囲の骨に現れる応力を算出した。その結果，インプラントを用いることで，設定した０～６mm 歯槽骨の吸収したモデルにおいて，von Mises stress が歯根膜部で 29.63 ～ 44.30% の減少した。インプラントとその周囲の骨に現れる応力は，きわめて小さかった。このことより，歯槽骨の吸収を起こしている歯に対して，加強固定の

ためにパラタルインプラントが有効であることが示唆された。

1. Introduction

The percentage of adult patients who seek orthodontic treatment has increased significantly in recent decades[1]. These patients often have bone loss in posterior teeth, which is often used as anchorage teeth. Excessive orthodontic force with advanced periodontal bone loss may traumatize the periodontium, and increased apical pressure because reduced bony support may contribute to apical root resorption[2]. Additional anchorage aid is often required for the posterior teeth with alveolar bone loss (ABL).

Routinely, headgears, transpalatal arches (TPAs) and Nance appliances are used to enhance anchorage during clinic treatment. However, many patients rejected headgear wear because of social and esthetic concerns and the success of this treatment depends entirely on patient cooperation[3]. In most studies on TPAs[4] and Nance appliance[5, 6], anchorage loss was unavoidable.

Implants, as a means of enhancing orthodontic anchorage, are gaining increased importance in orthodontic treatment because of the limitations and acceptance problems of conventional intraoral or extraoral anchorage aids[7, 8]. The median－sagittal region of the hard palate[9, 10] was described as a suitable location for implant placement because orthodontic patients generally have a complete dentition. This region is surgically very well accessible and offers excellent peri－implant conditions due to the attached mucosa. Palatal implant is often used to connect with the second premolar by a transpalatal arch to increase anchorage as shown in Fig. 1. There are some clinical studies[9, 10] showed that a palatal implant could offer enough anchorage effect. However, the alveolar condition of anchorage teeth was not well documented. The implant anchorage effect on the teeth with ABL has not been sufficiently explored. Hence there is a necessity to explore what occurred when the implant was used as an anchorage on the teeth with different ABL. As we know, an anchorage is related to periodontal stress[11] ; the anchorage effect of palatal implant can be explained by the redistribution of the periodontal ligament (PDL) stress of the natural teeth connected with the palatal implant.

Fig. 1. Palatal implant used as an orthodontic anchorage in the clinic. The second maxillary premolars were anchored by the implant through the transpalatal arch.

Finite element analysis (FEA) has been increasingly used for the prediction of the effects of stress on the tissues in orthodontics. FEA is a mathematical method in which the shape of complex geometric objects and their physical properties are computer constructed. Physical interactions of various component of the model are then calculated in terms of stress and strain.

The purpose of this study was to analyze the anchorage effect of the palatal implant by investigating periodontal stresses when the second premolar at different levels of alvelor bones loss.

2. Material and method

2.1 Model

2.1.1 Models with the implant: Model 1-4

Model 1(Fig. 2A) was composed of two maxillary premolars, PDL, alveolar bone, palatal implant, palatal bone, bracket, band, and TPA. The maxillary second premolar was created by manually designing the tooth according to dimension and morphology found in a standard dental anatomy textbook[12]. The outmost boundary of the tooth was first defined and sectioning the tooth into cross-sections created the third dimension. The tooth was reconstructed by inputting three-dimensional coordinates, defining the shape of the tooth into the Unigraphics NX 1.0 (Unigraphic solutions Inc.2002 California). Next the PDL, alveolar