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Original article

Histological response in dental pulp of accelerate tooth movement using periodontal ligament distraction osteogenesis in dogs

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ABSTRACT

Purpose: This study compared initial histological change in dental pulp in response to periodontal ligament distraction osteogenesis (PLDO) with that to conventional orthodontic treatment to determine the effectiveness of PLDO.

Materials and methods: PLDO was performed on the right side (PLDO group) and conventional orthodontic treatment on the left side (CCS group) in 6 male beagle dogs. Untreated teeth served as a control group. Radiographs were obtained after appliance activation. Change in pulpal blood flow was measured using a Doppler blood flow meter. The sections were stained with hematoxylin-eosin and Masson's trichrome for morphological observation. Cell response was observed by immunohistochemistry using proliferating cell nuclear antigen (PCNA) and the TUNEL method.

Results: The total movement distance of the premolar was significantly greater in the PLDO group than in the CCS group. A decrease in pulpal blood flow and the number of odontoblast cells was observed together with dental pulp capillary dilation at 5 and 12 days after appliance attachment in both groups. While many TUNEL-positive cells were observed on the 5th day in both experimental groups, they showed a decrease at 12 days. More PCNA-positive cells were observed on the 12th day than on the 5th day in both groups. There was no difference in invasiveness between the pulpal reaction to PLDO and that to conventional orthodontic treatment, suggesting that the level of recovery is similar.

Conclusion: PLDO enabled rapid tooth movement and initial histological change in the dental pulp was similar to that in response to conventional orthodontic treatment.

1. Introduction

Orthodontic treatment generally takes several years to complete, and shortening the time required is a major challenge in this field of dentistry. Various attempts to achieve this goal have been reported [1–12]. Periodontal ligament distraction osteogenesis (PLDO), first reported by Liou and Huang in 1998, is one such method [13]. In distracting a tooth into an extraction space, tooth movement can be

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acceleratedby planing the alveolar bone, which normally causes resistance. This method was reported to reduce the time required for closure of the extraction space, which generally takes 6 months or more, to approximately 3 weeks, with no harmful effects [8,9,12–18]. To the best of our knowledge, to date, many case reports and animal experiments have described periodontal tissue response to orthodontic tooth movement using PLDO, but very few have focused on that of dental pulp [17–19].

Apical displacement during orthodontic tooth movement causes circulatory disturbance in dental pulp tissue, resulting in hypoxia and odontoblastic apoptosis and a subsequent reduction in odontoblast count. As a result, differentiation of undifferentiated mesenchymal cells into odontoblasts occurs to compensate for the reduced number of odontoblasts. Finally, odontoblasts form reparative dentin and the series of dental pulp reactions is completed [20].

There are rare cases in which irreversible degeneration occurs due to hypoxia [21]. The amount of tooth movement with PLDO is greater than that with conventional orthodontic methods, so there is the danger of severe hypoxia occurring in the dental pulp [17–19,22–28]. Clarification of the reaction of dental pulp to PLDO is, therefore, important.

The purpose of this study was to compare the initial response of dental pulp to PLDO with that to the conventional method of orthodontic tooth movement, in which a wire is threaded through a normal bracket and tooth distalization performed with a closed-coil spring. Circulatory disturbance in the pulp was determined by laser Doppler blood flow measurement. TUNEL staining was used to investigate odontoblastic apoptosis and PCNA was used to investigate proliferation of odontoblasts.

2. Materials and methods

2.1. *Experimental animals*

Six male beagle dogs aged 10–15 months were used in the experiment. The 1st premolar was moved and the 3rd premolar was the anchor tooth. The right side was subjected to periodontal ligament distraction osteogenesis (PLDO group) and the left side conventional orthodontic treatment using a closed-coil spring (CCS group). Untreated teeth served as a control group. The 1st premolar specimens were prepared for examination on the 5th and 12th days from attachment of the appliance and histological change in the dental pulp observed.

Treatment procedures were performed after administration of local anesthesia with 2% lidocaine hydrochloride and under general anesthesia using medetomidine hydrochloride (20 mg/kg) and sodium pentobarbital (25 mg/kg) to minimize distress. Experimental animals were raised in individual cages with uniformly controlled light conditions and room temperature and fed soft dog food and water. The appliance, tooth, and gingiva were checked every day and cleaned with 0.02% chlorhexidine in water. The entire experimental protocol complied with the Animal Experimental Guidelines of Tokyo Dental College and was performed after receiving ethical approval (No. 232801).

2.2. *Distal movement appliance*

(i) Periodontal ligament distraction osteogenesis group (PLDO group)

First, orthodontic bands for the 1st and 3rd premolars were prepared within the oral cavity using band material with a thickness of 0.13 mm and width of 3.8 mm (Tomy International, Tokyo, Japan). Alginate impressions were immediately taken using individual trays and a working model fabricated after the band was restored to the impression body. Two premolar bands, a 3.0-mm diameter, 0.5-mm pitch stainless steel screw, and a 2.5-mm diameter guide bar were soldered onto the working model to fabricate an appliance for intraoral distal movement.

(ii) Closed-coil spring group (CCS group)

A working model similar to that made for the PLDO side was prepared and a 0.022-inch slot bracket (Tomy International, Tokyo, Japan) soldered. A 0.019 × 0.025 in. stainless steel wire (Ormco, Tokyo, Japan) was threaded through the bracket and traction of 150 g applied using a closed-coil spring (Tomy International, Tokyo, Japan). Force in the CCS group was determined according to the method of Ren et al. (Fig. 1) [12].

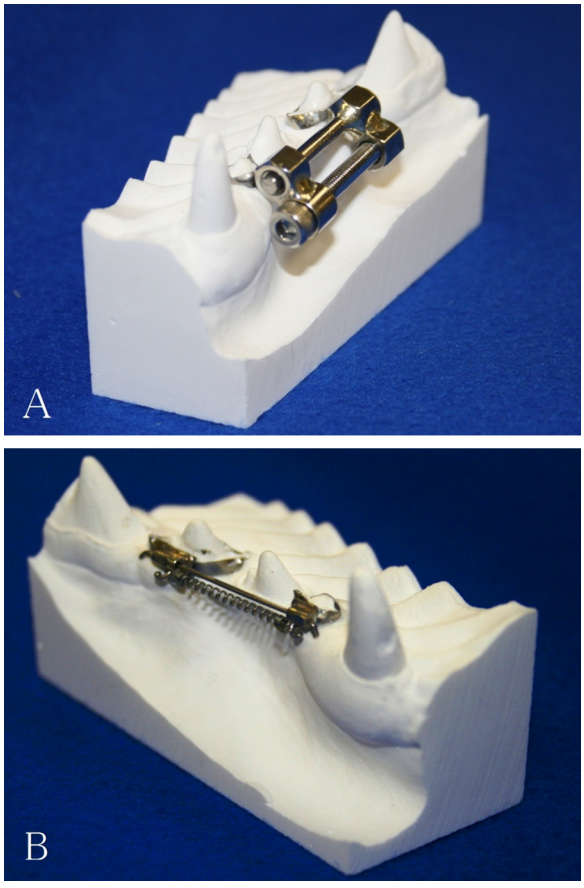

Fig. 1 – Intraoral appliance.
A: Intraoral appliance in PLDO group. One rotation results in movement of 0.5 mm.
B: Intraoral appliance in CCS group.