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Review

Behavior of the interdental proximal contact relation during function

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Introduction

In prosthetic treatment, sufficient recovery of the shape and function of the treated tooth is very important. To maintain a good condition for a long time after the treatment, the prosthesis must be in functional harmony with the stomatognathic system. It is very important to assure sufficient recovery of not only marginal fitness and occlusal contact, but also the interdental proximal contact relation with the adjacent teeth. Insufficient recovery of the latter can result in such problems as food impaction, periodontal disease, and proximal caries. The interdental proximal contact relation is usually checked in the static situation by using dental floss or metal strips. Food impaction has been shown to be closely related to occlusion[1]. For example, a plunger cusp may produce a functional opening of the contact between adjacent teeth. This allows food to be impacted in areas where the contacts may appear normal in the static situation. During function, biting forces apply stresses to the teeth, periodontal ligaments, mandible and maxilla and produce distortion in all of them[2]. Therefore, both the dynamic and static situations of the interdental proximal contact relation must be sufficiently understood.

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Over the past nearly half-century, many investigators have commented on the significance of clarifying physiological tooth displacement. Mühlemann[3], Parfitt[4], and others measured physiological tooth mobility in the static situation, whereas Schöhl[5], Behrend[6,7], Siebert[8,9], Kato[10,11], Miura[12,13], and others measured tooth displacement during function. Although a considerable part of physiological tooth displacement has become clear, the behavior of the interdental proximal contact during function has scarcely been measured.

Interdental contact relations in the static situation

Araki[14] measured the contact area and pressure of the interdental proximal contact and found that the contact areas of the upper anterior tooth, upper posterior tooth, lower anterior tooth, and lower posterior tooth were 0.31–2.38 mm^2, 0.33–6.07 mm^2, 0.38–2.46 mm^2, 0.38–3.88 mm^2 , respectively. He reported that a contact pressure was applied to the interdental proximal contact at rest. The contact pressures of the upper anterior tooth, upper posterior tooth, lower anterior tooth and lower posterior tooth were 0.9–23.47 gf, 2.30-23.53 gf, 0.12–12.49 gf and 1.05–27.59 gf , respectively. Southard[15] et al. also reported that teeth make contact with some pressure at rest. On the contrary, Yasunaga[16] reported that the majority of teeth did not make contact with an adjacent tooth in the static situation.

Teeth show a periodical displacement of about 0.5 μm at rest[10)] (Fig. 1). This corresponds with the heartbeat and is called tooth pulsation. It suggests that the interdental contact relation is passive in the static

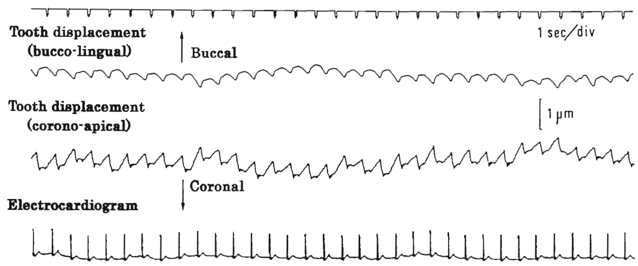

Fig. 1. Tooth pulsation (Kato[10]).

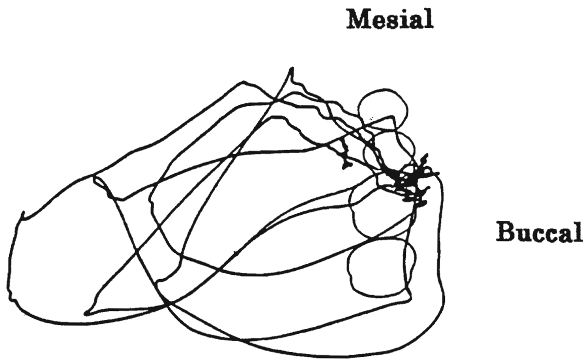

Fig. 3. The horizontal tooth displacement during mastication (loose interdental proximal contact relation).

situation, however, the detailed behavior of the interdental proximal contact has not, until recently, become clear.

Degree of interdental separation and tooth displacement

Kusakari[17] measured the degree of interdental separation by inserting steel strips (30, 50, 70, 90, 110, 130, 150, 170, 200, 300 μm thick) between the interdental proximal contact with a fixed pressure (1.2 kgf). He examined 792 interdental proximal contacts of 55 male and 7 female subjects (aged between 24 to 26). The degree of interdental separation of the upper and lower teeth was $92.5 \pm 51.6\,\mu$m and $70.3 \pm 37.56\,\mu$m, respectively. Food impaction frequently occurred when the degree of interdental separation was between 150 and 200 μm. Miura[13] measured the horizontal tooth displacement during function. The tooth with a normal interdental proximal contact relation (a 50 μm steel strip could be inserted with some resistance, but a 110 μm strip could not), showed a narrow displacement path in the mesio-distal direction during mastication (Fig. 2). The tooth displacement distance in the mesio-distal direction was 23 μm. In contrasts, the

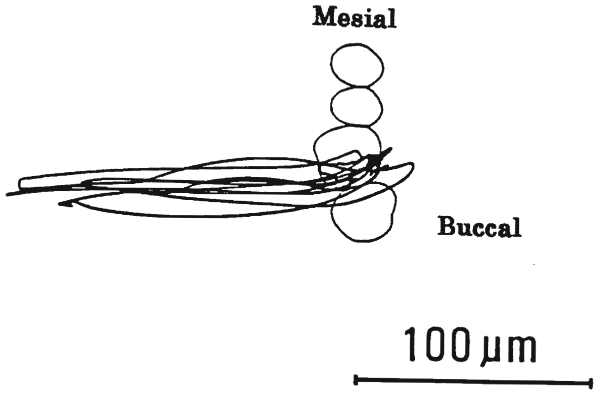

Fig. 2. The horizontal tooth displacement during mastication (normal interdental proximal contact relation).

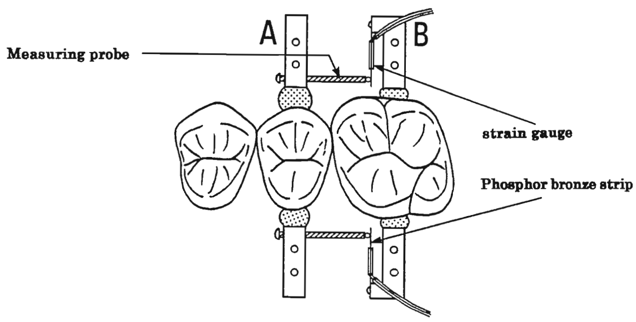

Fig. 4. The measuring device components.

tooth with a loose interdental proximal contact relation (a 110 μm steel strip could be inserted, but a 150 μm strip could not), showed a broad displacement path in the mesio-distal direction (Fig. 3). In this case, the displacement distance in the mesio-distal direction was 117 μm.

Interdental contact relations during function

To investigate the behavior of the interproximal contact relation, we measured the relative movement between the second premolar and the first molar in the mesio-distal direction. This measuring device was made up of two parts. One part had a strip of phosphor bronze with strain gauges on both sides (Fig. 4), and the other had the measuring probe (Fig. 4). These devices were fixed on the buccal and palatal surfaces of the upper left second premolar and first molar with fast-setting adhesive (Fig. 5). The measuring probe transmitted any changes in the distance between these teeth to the strain gauges, which transform any changes of the distance in the mesio-distal direction

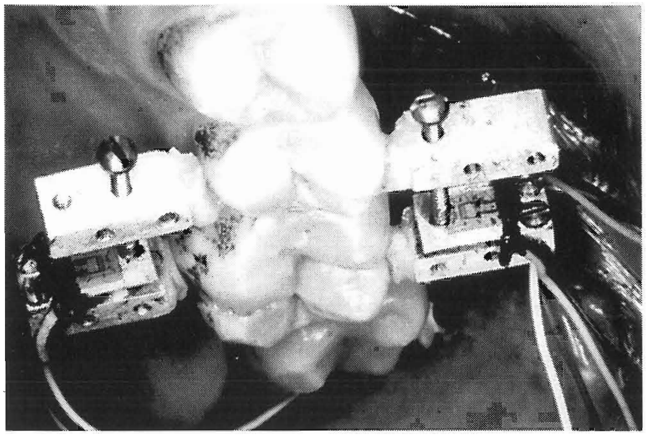

Fig. 5. The measuring device fixed in position.

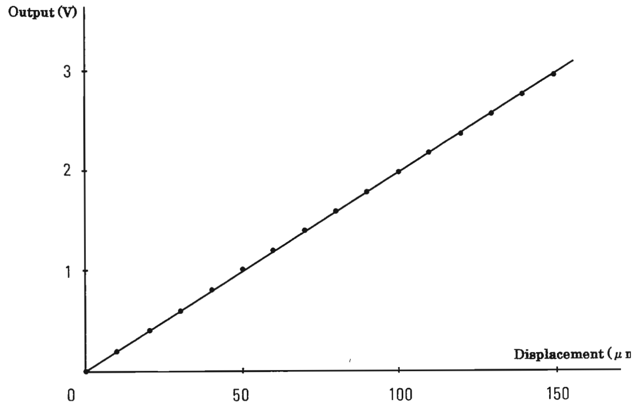

Fig. 6. The output characteristic of the transducer.

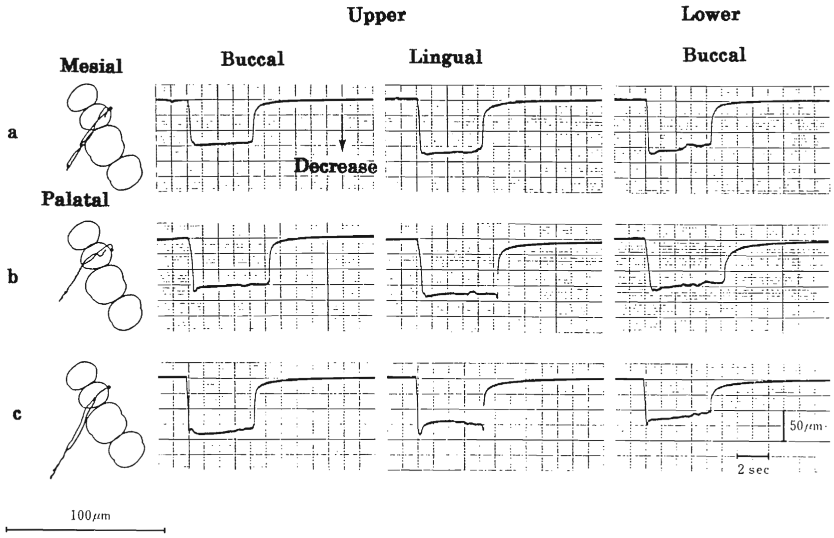

Fig. 7. The horizontal tooth displacement of the upper left second premolar and the relative movement between the second premolar and the first molar in the mesio-distal direction.
a: clenching at the intercuspal position.
b: biting 4 sheets of articulating paper.
c: biting 8 sheets of articulating paper.

into voltage changes. The output signals from the strain gauges were amplified at a rate of 20 mV/μm by a bridge box and a strain amplifier. These signals were monitored and recorded on an L-Cassette Data Recorder (Model FE 39A, Sony Magnescale Inc., Tokyo, Japan.).

The measuring pressure was about 5 g. We examined the accuracy of this measuring device; it showed linearity with a range of 0 to 150 μm (Fig. 6).

In this experiment, two male subjects (26 and 28 years old) were studied. They had normal dentitions and clinically healthy periodontal tissues. The relative movement between the left second premolar and first molar in the mesio-distal direction was investigated during teeth clenching at the intercuspal position with habitual occlusal force, biting 4 or 8 sheets of articulating paper, and chewing a piece of pretzel (substitute movement for mastication). The horizontal tooth displacement path of the upper left second premolar was simultaneously recorded with a tooth displacement transducer Type M. Electromyographic recordings were also taken from the masseter muscles with bipolar surface electrodes attached.

The displacement of the upper left second premolar and the relative movement of the second premolar and the first molar in the mesio-distal direction are shown in Fig. 7. For subject A, the relative distance between the second premolar and the first molar in the mesio-distal

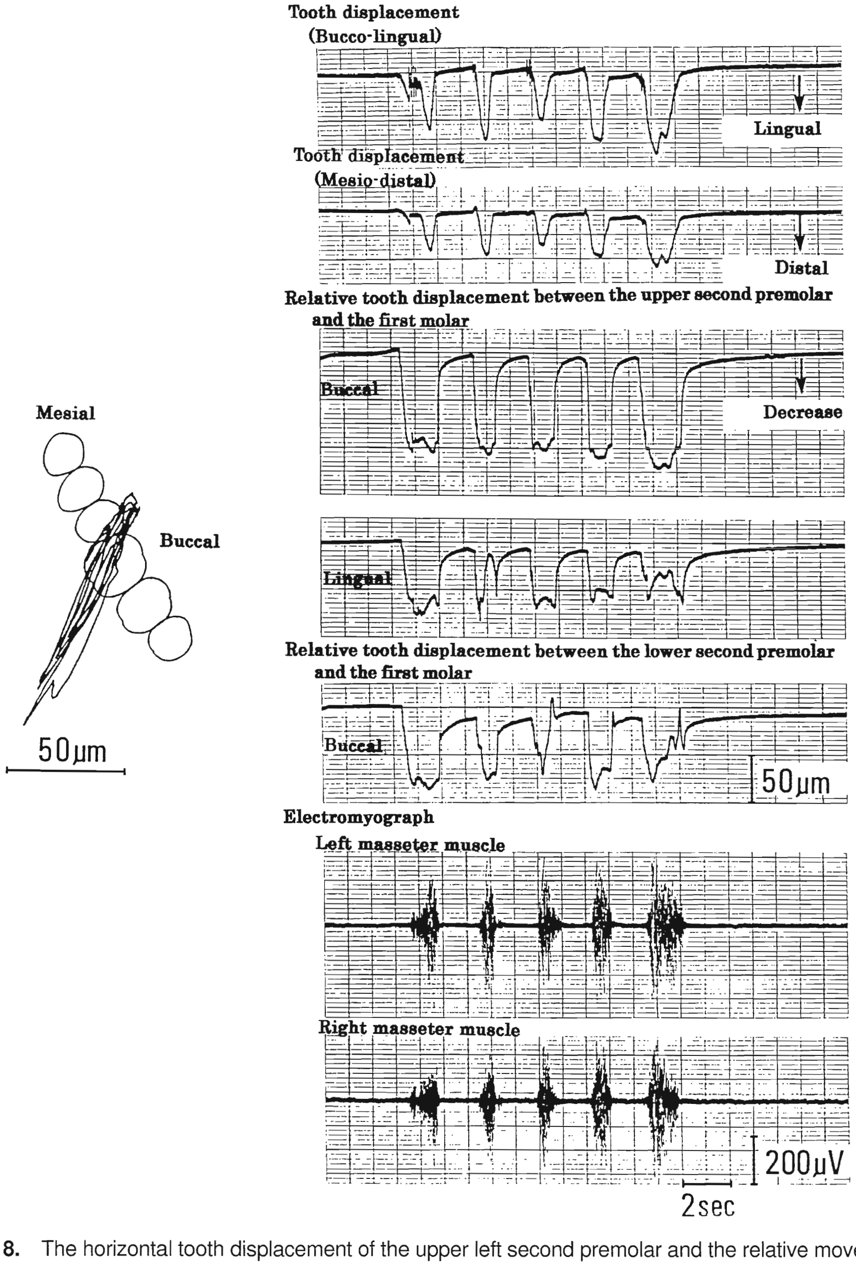

Fig. 8. The horizontal tooth displacement of the upper left second premolar and the relative movement between the second premolar and the first molar in the mesio-distal direction during mastication (Subject A).

direction decreased from 75 to 95 μm during clenching at the intercuspal position with habitual occlusal force or when biting 4 or 8 sheets of articulating paper. This reduction in distance was observed on both buccal and palatal surfaces. The upper second premolar was displaced between 48 and 69 μm in the distal and palatal directions during clenching at the intercuspal position with habitual occlusal force or when biting 4 or 8 sheets of articulating paper (Fig. 7).

The relative distance between the second premolar and the first molar in the mesio-distal direction decreased from 58 to 122 μm during mastication of a piece of pretzel (Figs 8 and 9). During mastication, the relative distance repeatedly decreased and recovered at every stroke. After the first stroke of mastication, the decrease began before recovery from the previous stroke had been completed. The amount of decrease was almost the same at every stroke. The decrease and recovery of the distance was observed on both the buccal and palatal surfaces (Figs 8 and 9). The upper

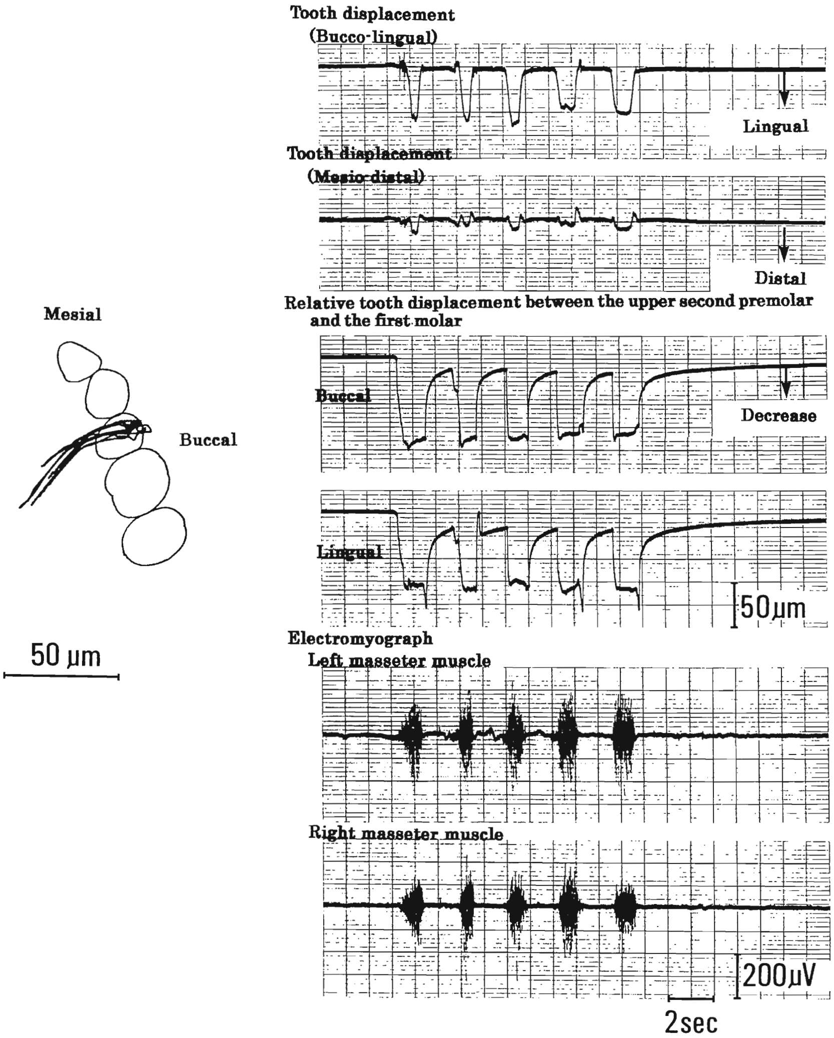

Fig. 9. The horizontal tooth displacement of the upper left second premolar and the relative movement between the second premolar and the first molar in the mesio-distal direction during mastication (Subject B).

second premolar showed a displacement of between 64 and 101 μm in the distal and palatal directions during mastication of a piece of pretzel (Figs 8 and 9).

Recently, Kasahara *et al.*[18] directly observed the behavior of the interdental proximal contact relation during clenching by using a charge-coupled device microscope. They detected spaces between the teeth by positioning a halogen light on the lingual side of the teeth and observing any changes in the light bands with the charge-coupled device microscope positioned on the buccal side. Two male subjects, aged 28 years with normal dentition, occlusion and interdental proximal contact relation were selected. For subject A, the light band was observed at rest between the interproximal contact of the maxillary right lateral and central incisors (Fig. 10). As the subject clenched at maximal intercuspation, each tooth contacted and separated the light band. Upon opening the jaw, the light band reappeared. Light intensity distribution analysis determined that there was an interproximal distance of more than 21 μm between the two incisors. Similar phenomena were observed between the maxillary left first and second premolars (Fig. 11), and between the mandibular left first and second premolars. Both of the interproximal distances between the maxillary and mandibular premolars were 3 μm. For subject B, light bands were also observed between the maxillary right lateral and central incisors (interproximal space was 9 μm), and between the mandibular left first and second premolars (interproximal space was 4 μm).

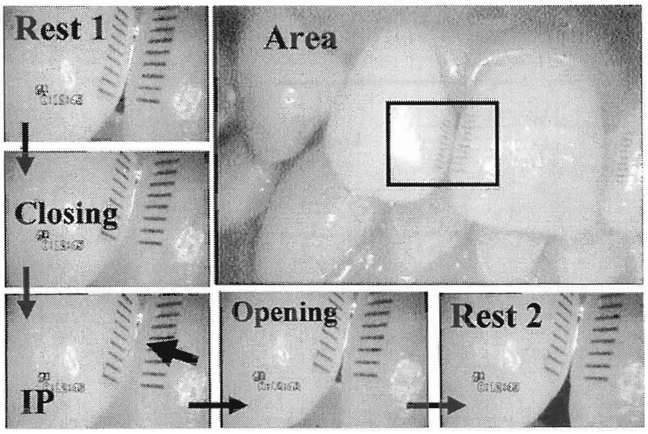

Fig. 10. Dynamics of the maxillary right lateral and central incisors during clenching (Kasahara *et al.*[18]).

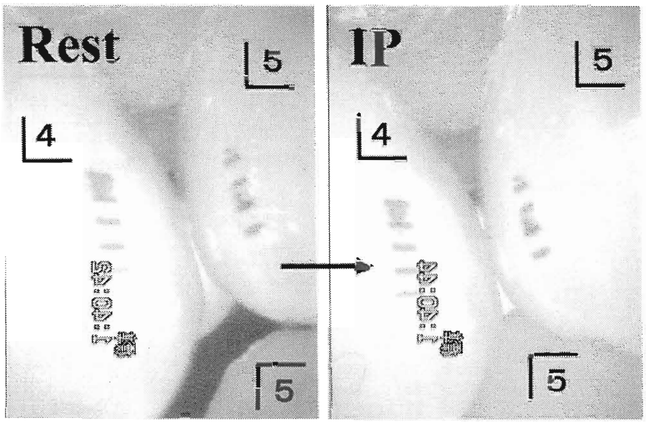

Fig. 11. Dynamics of the maxillary left first and second premolars during clenching (Kasahara *et al.*[18]).

From the facts described above, we may conclude that the examined tooth did not make contact with the proximal teeth at rest and pulsated in the alveolar bone mainly in response to the circulation of the blood in the periodontium. During mastication, the tooth was pushed into the alveolar bone and displaced in a direction toward a decrease in dental arch width. At the same time, the proximal contact became tighter, thus protecting the interdental papilla from food impaction.

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