Effect of Orthodontic Treatment on Occlusal Condition and Masticatory Function

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Abstract

Change in occlusion and masticatory function after orthodontic treatment was investigated by a follow-up study in a group of 14 patients with malocclusion (3 men, 11 women, aged 12–46 years). All completed a food questionnaire and underwent occlusal force evaluation using a pressure-sensitive sheet at pre-treatment, post-treatment, and during the retention phase. The number of foods identified as difficult to eat decreased at post-treatment in all patients. The mean occlusal force was 646.6 ± 223.5 N at pre-treatment, 401.1 ± 109.1 N at post-treatment, and 530.6 ± 183.6 N during the retention phase. The mean occlusal contact area was 14.1 ± 5.9 mm² at pre-treatment, 6.5 ± 1.7 mm² at post-treatment, and 9.8 ± 3.8 mm² during the retention phase. The mean average occlusal pressure was 47.6 ± 6.6 MPa at pre-treatment, 62.2 ± 5.7 MPa at post-treatment, and 55.4 ± 6.7 MPa during the retention phase. A Dental Prescale film evaluation revealed that occlusal force and occlusal contact area increased over the 1-year retention phase. An improvement in level of satisfaction with mastication ability was reported at post-treatment and during the retention phase. Average occlusal pressure at post-treatment increased significantly (p < 0.01), which may account for the observed increase in the ability of the patients to bite through food. These results suggest that an increase in average occlusal pressure improves level of satisfaction with mastication ability.

Key words: Dental prescale — Food questionnaire — Occlusal contact area — Average occlusal pressure — Orthodontic treatment

Introduction

Proffit et al.¹⁴ described how changes in the goals of orthodontic treatment, which are to focus on facial proportions and the impact of the dentition on facial appearance, have now
been codified into the soft tissue paradigm. Final occlusion on completion of orthodontic treatment is determined based on morphological, functional, and esthetic considerations. Few studies, however, have investigated the effect of occlusal contact on masticatory function.

Miyatani et al.\textsuperscript{11} preoperatively administered a food questionnaire in patients with malocclusion and carried out a survey using Dental Prescale film to investigate the difference between subjective and objective satisfaction with mastication. Dental Prescale film allows occlusal force, occlusal contact area, and average occlusal pressure to be quantified quickly and easily. The results revealed that although patients with malocclusion did not regard any particular foods as difficult to eat, occlusal force and occlusal contact area in these patients did not match those in individuals with normal occlusion. Hirose et al.\textsuperscript{5} used the chewing gum method to investigate change in masticatory function as a result of orthodontic treatment in patients with malocclusion. They reported that masticatory function varied depending on type of malocclusion, although there was no difference between those with maxillary prognathism and individuals with normal occlusion, and this did not change as a result of orthodontic treatment. In cases of crowding or underbite, however, masticatory function was inferior to that with normal occlusion and was improved by orthodontic treatment.

Most such studies have been cross-sectional, however, and few reports have compared occlusal condition in the same individual between at pre- and post-treatment\textsuperscript{5,6,7}. In a wide-ranging search of the literature, the present authors were unable to identify any prospective studies on this topic or of an association between masticatory function at these two time points and change in subjective evaluation of mastication ability.

Therefore, the purpose of the present study was to investigate change in level of satisfaction with masticatory ability and its relationship to occlusal condition following orthodontic treatment by conducting a follow-up in patients from pre- to at 1 year post-treatment using Dental Prescale film and a food questionnaire as an objective and subjective means, respectively, of evaluation. The hypothesis was that occlusal force would continue to increase after treatment.

**Methods**

1. **Study participants**

Informed consent was obtained from all patients participating in the study. The study protocol was carried out in compliance with the Helsinki Declaration and with the approval of the Ethics Committee of Tokyo Dental College (Approval No.531).

A total of 43 patients with malocclusion (10 men, 33 women) and permanent dentition were enrolled in the study. All were randomly selected from patients attending the Department of Orthodontics at Tokyo Dental College Chiba Hospital between September 2007 and July 2008. All were required to complete a food questionnaire\textsuperscript{1,11} and undergo occlusal force evaluation by means of a pressure-sensitive sheet (Dental Prescale 50H type R, Fuji Photo Film Co.) at pre-treatment.

Of these, 16 patients (4 men, 12 women) also completed the same questionnaire and underwent occlusal force evaluation soon after conclusion of treatment and appliance removal; and of these, 14 (3 men, 11 women) underwent a further occlusal force evaluation after 1 year or more of retention (Table 1). The mean age of the patients on data acquisition was $23.1 \pm 8.5$ years (12–46 years) at pre- and $26.2 \pm 9.8$ years (15–50 years) at post-treatment, with orthodontic treatment lasting for a mean period of 31 months. Evaluation at post-treatment was performed after a mean period of $2.6 \pm 1.9$ months (1–6 months) following appliance removal. After appliance removal, retainers used in the maxilla included a circumferential removable plate retainer in combination with a fixed retainer in 3 patients and a circumferential removable plate retainer in 11 patients; those used in the mandible included a circumferen-
tial removable plate retainer in combination with a fixed retainer in 3 patients, a circumferential removable plate retainer in 1, and a fixed plate retainer in 10 (Table 1).

Evaluation during the retention phase was performed after a mean period of 14.8 ± 2.2 months following appliance removal.

One limitation of this study was that, despite calling the patients within 6 months post-treatment, not all responded as hoped, which generated a time discrepancy in data collection.

2. Classification of patients

1) Extraction

The extraction group (10 patients) consisted of patients in whom either the four upper and lower premolars or the two premolars in either the upper or lower jaw had been extracted; the non-extraction group (4 patients) consisted of patients in whom no teeth had been extracted. No account was taken of whether the upper or lower third molar was extracted in either group.

2) Treatment plan

The orthodontic group (9 patients) underwent orthodontic treatment alone; the surgical orthodontic group (5 patients) underwent surgical orthodontic treatment. Members of the surgical orthodontic group were further subdivided into those who underwent orthodontic surgery on both the upper and lower jaws and those who underwent it on the lower jaw only.

3. Methods

1) Questionnaire

The questionnaire$^{111}$ covered 55 foods and was selected in reference to a food questionnaire used to evaluate masticatory function in denture wearers and temporomandibular joint disorder patients and food categories measured in studies on food properties and ingestion function. The patients were required
Questionnaire covered 55 foods selected on basis of food questionnaire used to evaluate masticatory function in denture wearers and temporomandibular joint disorder patients and of food categories measured in studies on food properties and ingestion function. Patients were required to select one of following 5 descriptions regarding each food: (1) easy to eat; (2) difficult to eat but can be eaten with some effort; (3) not eaten as too difficult to eat; (4) not eaten as disliked or allergic; or (5) don’t know.
to select one of the following five descriptions regarding each food: (1) easy to eat; (2) difficult to eat but can be eaten with some effort; (3) not eaten as too difficult to eat; (4) not eaten as disliked or allergic; or (5) don’t know. The questionnaire was conducted at pre- and post-treatment. Patients who selected (2) or (3) in the survey were classified as having foods that they felt difficult to eat (Fig. 1).

2) Occlusal force measurement device and method of measurement

A pressure-sensitive sheet (Dental Prescale 50H type R) and an Occluzer FPD-709 dental occlusion pressure measurement device (Fuji Photo Film Co., Figs. 2 and 3) were used to measure occlusal contact area, average occlusal pressure, and occlusal force.

Measurements were taken with the patients in a seated posture and with the Frankfort horizontal plane parallel to the floor. The patients were required to bite down as hard as they could on the Dental Prescale film in the intercuspal position for 3 sec, during which time the colored areas were scanned with the Occluzer and the results quantified. Occlusal force was measured at pre- and post-treatment and during the retention phase.

3) Statistical analysis

Occlusal force, occlusal contact area, and average occlusal pressure were measured at pre- and post-treatment and during the retention phase. The values obtained were compared statistically. A repeated measures ANOVA was used for a comparison among the three groups, followed by Bonferroni correction for comparisons between the different groups. The patients were also classified by type of treatment. A two-way ANOVA was used for comparisons among groups. A level of p < 0.05, p < 0.01 was considered statistically significant.

Results

1. Questionnaire

At pre-treatment, 9 patients responded that they found none of the 55 foods difficult to eat, 3 found 1–4 foods difficult to eat, and 2 found 5 or more foods difficult to eat. Foods that were identified as difficult to eat included French bread, beef steak, squid sashimi, and almonds. At post-treatment, 13 patients responded that they found none of
the 55 foods difficult to eat, and 1 patient found 1 food difficult to eat. This patient also mentioned that *takuan* (pickled daikon radish) was difficult to eat, even after treatment (Table 2).

The number of foods identified as difficult to eat decreased after treatment in all patients. During the retention phase, the patients similarly reported that no foods were difficult to eat in daily life, and no change was observed in their subjective evaluation between at post-treatment and during the retention phase.

**2. Change in occlusal force**

Mean occlusal force was $646.6 \pm 223.5$ N at pre-treatment, $401.1 \pm 109.1$ N at post-treatment, and $530.6 \pm 183.6$ N during the retention phase (Fig. 4). The repeated measures ANOVA revealed significant differences ($p<0.01$). Further analysis with Bonferroni correction showed significant differences between pre- and post-treatment ($p<0.01$), and also between post-treatment and during the retention phase ($p<0.01$).

In the extraction group, mean occlusal force was $676.9 \pm 180.5$ N at pre-treatment, $398.4 \pm 118.5$ N at post-treatment, and $495.6 \pm 158.3$ N during the retention phase; in the non-extraction group, it was $570.9 \pm 328.8$ N at pre-treatment, $407.7 \pm 96.6$ N at post-treatment, and $618.3 \pm 237.9$ N during the retention phase (Fig. 5). The two-way ANOVA revealed no significant difference.

In the orthodontic group, mean occlusal force was $588.3 \pm 207.5$ N at pre-treatment, $400.7 \pm 103.1$ N at post-treatment, and $519.3 \pm 140.3$ N during the retention phase; in the surgical orthodontic group, it was $751.6 \pm 234.2$ N at pre-treatment, $401.8 \pm 132.0$ N at post-treatment, and $551.0 \pm 263.4$ N during the retention phase (Fig. 5). There was no significant difference.

**3. Change in occlusal contact area**

Mean occlusal contact area was $14.1 \pm 5.9$ mm² at pre-treatment, $6.5 \pm 1.7$ mm² at post-treatment, and $9.8 \pm 3.8$ mm² during the retention phase (Fig. 6). A significant difference was observed among the three groups.
There were significant differences between at pre- and post-treatment \((p < 0.01)\), between post-treatment and during the retention phase \((p < 0.01)\), and also between pre-treatment and during the retention phase \((p < 0.05)\).

Mean occlusal contact area in the extraction group was \(14.5 \pm 3.9\) mm\(^2\) at pre-treatment, \(6.3 \pm 1.8\) mm\(^2\) at post-treatment, and \(9.2 \pm 3.6\) mm\(^2\) during the retention phase; in the non-extraction group, it was \(13.1 \pm 10.1\) mm\(^2\) at pre-treatment, \(7.0 \pm 1.3\) mm\(^2\) at post-treatment, and \(11.1 \pm 4.6\) mm\(^2\) during the retention phase (Fig. 7). There was no significant difference.

In the orthodontic group, mean occlusal contact area was \(12.2 \pm 4.8\) mm\(^2\) at pre-treatment, \(6.5 \pm 1.4\) mm\(^2\) at post-treatment, and \(9.9 \pm 3.1\) mm\(^2\) during the retention phase; in the surgical orthodontic group, it was \(17.4 \pm 6.6\) mm\(^2\) at pre-treatment, \(6.5 \pm 2.3\) mm\(^2\) at post-treatment, and \(9.5 \pm 5.3\) mm\(^2\) during the retention phase (Fig. 7). There was no significant difference.

The Dental Prescale images also revealed that the balance of the occlusal contact area frequently became more uniform after orthodontic treatment, with a smaller occlusal contact area and point contact (Fig. 8).

### 4. Change in average occlusal pressure

Average occlusal pressure was \(47.6 \pm 6.6\) MPa at pre-treatment, \(62.2 \pm 5.7\) MPa at post-treatment, and \(55.4 \pm 6.7\) MPa during the retention phase (Fig. 9). A significant difference was observed among the three groups \((p < 0.01)\). Significant differences were observed between at pre- and post-treatment \((p < 0.01)\), post-treatment and during the
Retention phase (p < 0.05), and also between pre-treatment and during the retention phase (p < 0.05).

Average occlusal pressure in the extraction group was 47.4 ± 6.4 MPa at pre-treatment, 63.7 ± 5.5 MPa at post-treatment, and 55.2 ± 7.5 MPa during the retention phase; in the non-extraction group, it was 48.2 ± 8.2 MPa at pre-treatment, 58.2 ± 4.7 MPa at post-treatment, and 55.9 ± 5.0 MPa during the retention phase (Fig. 10). There was no significant difference.

In the orthodontic group, average occlusal pressure was 49.2 ± 4.3 MPa at pre-treatment, 61.8 ± 4.8 MPa at post-treatment, and 53.1 ± 5.2 MPa during the retention phase; in the surgical orthodontic group, it was 44.7 ± 9.4 MPa at pre-treatment, 62.8 ± 7.8 MPa at post-treatment, and 59.6 ± 7.6 MPa during the retention phase (Fig. 10). There was no significant difference.

**Discussion**

Proffit et al.\(^{(15)}\) described retention as follows: (1) the gingival and periodontal tissues are affected by orthodontic tooth movement and require time for reorganization when the appliances are removed, (2) the teeth may be in an inherently unstable position after the treatment, so that soft tissue pressures con-
stantly produce a relapse tendency, and (3) changes produced by growth may alter the orthodontic treatment result. Proffit also noted that securing the teeth with a very stiff wire might prevent the recovery of normal periodontal structures. When individual teeth react to mastication after appliance removal, it takes 3 to 4 months for reorganization of the periodontal membrane to occur and vibration seen immediately after appliance removal to disappear; reorganization of the gingival fibers also occurs within 6 months, but a longer time is required for reorganization of elastic alveolar crest fibers. In the present study, we evaluated occlusal force at pre- and post-treatment (shortly after removal) and during the retention phase (one year or more after removal). The reduction in occlusal force observed here at post-treatment may have resulted from instability of occlusion shortly after removal.

1. Study participants

Those participating in this study were randomly selected from patients with malocclusion and permanent dentition. No classification was made based on age, sex, type of malocclusion, or facial morphology. All the patients had finished growing and were evaluated based solely on treatment policy and extraction.

2. Occlusal force measurement device and method of measurement

Dental Prescale film and the Occluser FPD-709 were used to measure occlusal contact area, average occlusal pressure, and occlusal force. To minimize error during measurements, the Prescale film was fed into the
Occluzer immediately after being bitten on to avoid the effect of change in color density and area over time and the data quantified.

Dental Prescale consists of two thin sheets of film enclosing a colorless dye that breaks down as a result of occlusal pressure and becomes colored in proportion to the occlusal pressure as the result of a chemical reaction. This is then analyzed by the Occluzer to enable measurement of parameters including average occlusal pressure, maximum occlusal pressure, average occlusal pressure, occlusal force, occlusal force balance, occlusal force distribution, and partial occlusal force. Yamaguchi et al.\(^{19}\) stated that, close to the intercuspal position, the Prescale is capable of precise measurement of occlusal contact pressure, and offers useful information on occlusion if due consideration is given during clinical use.

3. Questionnaire

In this study, a food questionnaire was also administered to allow a comparison of subjective data with the objective data on occlusion obtained with the Dental Prescale at each time point.

Saito et al.\(^{16}\) administered a food intake questionnaire in patients with malocclusion to investigate the association between occlusal condition and ease or difficulty of eating various different types of food. They scored the questionnaire items to arrive at an objective evaluation of degree of ease or difficulty of eating.

According to Abe et al.\(^{1}\), foods regarded as difficult to eat combined hardness, elasticity, cohesiveness, and adhesiveness.

In this study, the results of the questionnaire suggest that satisfaction with level of mastication improved at post-treatment in all patients. The sense of difficulty felt by patients when eating cohesive or adhesive foods may have been ameliorated here as a result of the better cleanability of the dentition following orthodontic treatment.

4. Dental Prescale measurement results

The results of the Dental Prescale measurement of occlusal change over time revealed that both occlusal force and occlusal contact area decreased at post-treatment compared with at pre-treatment, but average occlusal pressure increased. During the retention phase, occlusal force and occlusal contact area were comparable with or slightly less than at pre-treatment, but increased compared with at post-treatment. Average occlusal pressure during the retention phase increased compared with at pre-treatment, but decreased compared with at post-treatment.

It can be seen from the various Dental Prescale images obtained at pre-treatment that the occlusal contact area was uneven, with a large occlusal contact area providing surface contact mainly in the molar region, suggesting attrition of the teeth. Schaerer et al.\(^{17}\) found that occlusal interference caused tooth movement and attrition. In individuals with malocclusion, mastication causes tooth movement and attrition. Moreover, this also occurs in the intercuspal position, even when malocclusion is present.

According to Kitafusa\(^ {9}\), occlusal force, occlusal contact area, and average occlusal pressure are greatest in cases of mandibular prognathism, crowding, maxillary prognathism, cross bite, and open bite, in that order. Among the present 14 patients undergoing further occlusal force evaluation after 1 year or more of retention, 2 showed large occlusal forces of $\geq$900 N at pre-treatment, and both were cases of mandibular prognathism.

The Dental Prescale images also show that the balance of occlusal contact area frequently became more uniform at post-treatment compared with at pre-treatment, with a smaller occlusal contact area and point contact (Fig. 8). However, the average occlusal pressure imposed on a small contact area was found to rise, which would explain why the patient was inclined to bite. As the average occlusal pressure increased at post-treatment and occlusal force decreased, it would have become possible to bite through food by using less force than at pre-treatment, and this may have contributed to raising patient satisfaction with their ability to masticate foods that had been
difficult to eat in terms of their hardness or elasticity.

The Dental Prescale images from the retention phase show an increase compared with at post-treatment.

A comparison between the surgical orthodontic and orthodontic groups revealed that, although occlusal force and occlusal contact area were larger at pre-surgery in the former, there was no difference between the two groups at post-treatment or during the retention phase.

Hin et al.\(^4\) classified 70 adult women who underwent surgical orthodontic treatment according to cross-sectional data into the following five groups by treatment or observation period: 1) a pre-treatment group; 2) a pre-surgical group; 3) a 1-year post-operative group; 4) a 1- to 3-year post-operative group; and 5) a 3-year post-operative group. The average maximum occlusal force in the pre-treatment, pre-surgical, and 3-year post-operative groups was approximately 60, 40, and 70% of that in the control group, respectively. No significant difference was observed between the pre-treatment and 3-year post-operative group. The changes in occlusal contact area were similar to those in maximum occlusal force. Furthermore, no significant difference was observed between the pre-treatment and 1-year post-treatment groups.

Nanda and Burstone\(^13\) categorized factors contributing to occlusal stability after orthodontic treatment as (1) change related to growth, maturation, and aging of the dentition and occlusion; and (2) change related to inherent instability of occlusion produced by orthodontic therapy. Although it appears at first glance that periodontal membrane fibers and gingival fibers are reconstituted during the tooth movement phase by orthodontic treatment, in some cases these fibers may cause regression within a short time after treatment. As investigations were carried out soon after appliance removal in the present study, no reconstitution of periodontal tissue was observed which would have rendered it incapable of fulfilling its function adequately.

On the other hand, data on the retention phase were obtained more than a year after it was commenced, which may explain why function at this point was better than at post-treatment.

Andrews\(^2\) states that enlarging occlusal contact between the upper and lower jaws is important in achieving good dentition and occlusion and maintaining it over the long-term, and McLaughlin et al.\(^10\) recommend exchanging the wire for a .014 round wire in the final phase of treatment to achieve close occlusion. Tamura et al.\(^16\) switched from a thick rectangular wire to a fine round wire before appliance removal, and found that Prescale measurement revealed that occlusal contact area and occlusal force increased as a result. In the present study, however, no reduction was made in wire size in the final stage of treatment. Further observation may be required to investigate whether the method recommended by McLaughlin and Tamura is associated with an increase in occlusal force.

Retention refers to retaining teeth that have been moved by means of orthodontic treatment in their new positions. In recent years, it has become recognized that morphologically stable occlusion with good function can be maintained even after a long time has elapsed since treatment.

Kitafusa\(^8\) used Dental Prescale film to evaluate occlusal condition at before and immediately after orthodontic treatment and after at least 1 year of retention had elapsed. They reported that occlusal contact area and occlusal force increased significantly from at immediately after treatment to during the retention phase.

Nakashima and Takahama\(^12\) compared masticatory function between at before and after orthodontic treatment and after retention and found that, although masticatory function is not necessarily increased by orthodontic treatment, it does increase in the retention phase. One occlusal contact should be point contact so that there is no CO-CR discrepancy, so-called centric slide displacement, when active orthodontic treatment has been completed. Occlusal force is the prod-
uct of average occlusal pressure and occlusal contact area. Therefore, reduction of the area will lead to a reduction in occlusal force.

Here, the occlusal contact area was reduced to a point at post-treatment with no subsequent observation of slide on occlusal contact. We believe that this was why there was no marked reduction in occlusal force. Moreover, although average occlusal pressure did show a reduction during the retention phase, an improvement was still maintained in comparison with at pre-treatment, with an increase being observed in occlusal contact area from post-treatment through retention. In the present study, average occlusal pressure at post-treatment showed a significant increase, while occlusal force and occlusal contact area showed a significant increase during the retention phase. This suggests that during the subsequent retention period, mastication may cause dental attrition, increasing occlusal contact sites and further improving masticatory function. Occlusal force can be predicted to increase during the retention phase.

In addition, increased occlusal pressure during mastication may have increased the ability of the patients to bite through the food. All the patients reported an improvement in level of satisfaction with mastication at post-treatment, suggesting that this was due to the increase in average occlusal pressure.

**Conclusion**

Evaluation of occlusal force and occlusal contact area during retention using Dental Prescale film revealed an increase in both during the year-long retention phase.

The results of the questionnaire suggest that satisfaction with mastication improved at post-treatment and during the retention phase compared with at pre-treatment. Average occlusal pressure showed a significant increase at post-treatment. These results suggest that an increase in average occlusal pressure improves the level of satisfaction with mastication and that an increase in occlusal force occurs during the retention phase.

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**Conflict of Interest**

There is no conflict of interest in this study.

**References**


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