European Journal of Orthodontics 26 (2004) 73–78

European Journal of Orthodontics vol. 26 no. 1

Psychophysical testing of taste and flavour reactivity in young patients undergoing treatment with removable orthodontic appliances

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SUMMARY Upper removable appliances (URA), as well as full dentures, are known to be the cause of various complaints related to oral handling of food and beverages, phonation and vocalization, in addition to general discomfort.

To test the hypothesis that taste and flavour perception might also be affected by URA, 22 young orthodontic patients (10 males and 12 females aged 11.5 ± 1.7 years; experimental group) wearing URA and 17 subjects (seven males and 10 females aged 11.6 ± 2.0 years; control group) not wearing any orthodontic appliances were presented with a battery of eight intra-oral gustatory and three retro-nasal flavour stimuli. The subjects in the experimental group were tested on three different occasions and those in the control group on two occasions. All participants were required to label verbally the perceived taste and flavour sensations, as well as to estimate the palatability and intensity of the perceived sensation on a 100 mm visual analogue scale (VAS). Means and standard deviations were calculated from the individual values and then compared between the two groups and among the different testing times. Statistical significance was assessed with a level of confidence set at 0.025.

The results revealed no significant difference between the indicative values chosen to represent taste and flavour reactivity, neither between the groups nor among different dates of testing within each group. Orthodontists should therefore encourage patients to also use the URA during meals, without any detrimental effect on taste and/or flavour perception.

Introduction

The senses of taste and smell are among the regulatory mechanisms for acceptance or rejection of food. Insertion of an upper removable appliance (URA) changes the oral environment and adaptation difficulties have been reported (Stewart *et al.*, 1997; Sergl and Zenter, 1998). Speech disturbances are known to be among the major concerns of URA wearers (Sergl and Zentner, 1998). However, disturbances in taste and smell have not yet been studied, in spite of complaints and questions from patients and their parents regarding these functions. The only existing evidence of a possible effect of a removable appliance originates from adult patients using full maxillary dentures who often complain about disturbed taste sensation (Taylor and Doku, 1963; Bates and Murphy, 1968).

Clinical experience suggests that a URA might affect taste and smell by disturbing the natural airflow between the oral and nasal cavities. Airflow is essential for the identification of retro-nasal flavour stimuli evoked during mastication and the URA prevents regular contact between the palatal receptor sites and the taste samples. Thus, the aim of this study was to evaluate the possible influences of wearing a URA on the detection and identification of taste and flavour sensations from the oral cavity.

Subjects and methods

Subjects

Two groups of children participated in the study: 35 patients treated with a URA and a matching control group of 30 untreated children. All subjects were free of systemic diseases, had not had previous orthodontic treatment and at the time of the examination did not suffer from any acute problems in their upper respiratory tract. The experiment was approved by the Institutional Review Board of the Hadassah Medical Centre.

Of the original group of 65 subjects, nine individuals failed to complete all the scheduled examination sessions and 17 were found to be unreliable (based on marked inconsistency in labelling identical stimuli). Therefore, the final number of participants was 39. The demographic data of the two groups are presented in Table 1.

The removable appliance

All of the URAs used were constructed at the same orthodontic laboratory utilizing self-curing acrylic and stainless steel wires. The appliances were prepared approximately 24 hours before delivery to the patient, rinsed in water, dried and stored in sealed nylon bags.

Table 1 Demographic data of the experimental and control groups.

	Experimental group	Control group
n	22	17
Boy/girl ratio	10/12	7/10
Mean age ± standard deviation (years)	11.5 ± 1.7	11.6 ± 2.0
Age range (years)	9–16	9–16
Median age (years)	11	11

Taste stimuli

Each subject received a series of eight 5 ml samples representing tasteless, sweet, salty and sour substances in a random order. All intra-oral stimuli were presented in disposable plastic cups at room temperature. These were distilled water and aqueous solutions of analytically pure chemicals in the following concentrations: sucrose 0.3 and 0.03 M (labelled as stimulants A and B, respectively), citric acid 0.24 and 0.024 M (labelled as stimulants C and D, respectively) and NaCl 0.9 and 0.09 M (labelled as stimulants E and F, respectively). Distilled water was presented in two samples (labelled as stimulants G and H).

Flavour stimuli

As retro-nasal stimuli, three samples of chewing gum were chosen. These were of identical texture, colour and hardness ('West', Ion S.A., Greece). The samples differed only in their flavour: mint (1), banana (2) or orange (3).

Examination

All examinations were performed in a dental chair. The samples were presented to the subjects in an individual, randomized sequence. The patients were instructed to keep the solutions or chewing gum samples in their mouth until the taste or flavour was identified. The time that elapsed between the introduction of the sample into the mouth and identification by the patient was measured with a stopwatch and recorded by the examiner (accuracy up to 0.5 seconds). Between each of the samples the subjects rinsed their mouth with tap water. The mean duration of the whole testing session was approximately 6 minutes.

In each session the participants were requested:

1. to write down in their own words the description of the taste or flavour (verbal labelling);
2. to mark the palatability (hedonic estimation) on a visual analogue scale (VAS);
3. to mark the intensity estimation of the stimulus on a VAS.

The participants were asked to mark their answers on forms with 100 mm VAS. The scales were horizontal lines with their endpoints marked by anchor statements. The statements were 'most pleasant' (right-hand side) and 'most repulsive' (left-hand side) for the palatability (hedonic) estimates. Another VAS was used to record intensity estimates, with the endpoints marked by the anchor statements 'strongest' (right-hand side) and 'weakest' (left-hand side).

The subjects were instructed to make a single and decisive, clearly visible mark on each of the scales, according to their best subjective judgement.

The entire testing procedure was repeated in three sessions for the orthodontic patient group according to the following timetable: T_0, a mean of 10 days before insertion of the URA; T_1, immediately after insertion of the URA; T_2, 1 month after insertion of the URA.

The subjects in the control group were tested only twice, with at least 2 weeks between the sessions (T_0'; T_1').

Data processing

1. The mean and standard deviation of the identification time of each sample and session were calculated.
2. The verbal labelling was evaluated dichotomously as 'correct' or 'incorrect'. The percentage of 'correct' identifications for each taste or flavour stimulus was calculated.
3. For both of the estimates, the distance between the left-hand side of the VAS and the subject's mark was measured in millimetres (to an accuracy of 0.5 mm). The individual measurements were charted. From the obtained individual semi-quantitative estimates, means and standard deviations were calculated.
4. The reliability of the subjects was established based on the identification of the two distilled water samples. They were considered consistent according to the following criteria: (a) the verbal labelling of the two distilled water samples (G and H) was described as 'tasteless' or 'water'; (b) the difference between the two values given for each of the requested estimates on the VAS did not exceed 7 mm.

Based on these criteria, 17 patients were excluded from the study because of inconsistency.

Comparisons were made between the two groups and among different testing times within each group.

Statistical evaluation

A Student's *t*-test was used to evaluate the continuous variables (reaction time, intensity and hedonic estimates). Evaluation of the non-continuous variable (correct verbal labelling) was undertaken using χ^2 and McNemar tests. Due to the multiple comparisons applied in this

study and as cumulative error was suspected, the confidence level was established at $P = 0.025$.

Results

Correct verbal labelling of taste and flavour stimuli (Figure 1)

The majority of stimuli were labelled correctly by both groups. The most accurate identification was for the distilled water (G and H), while the most erroneous identification was for the low concentration sucrose solution (B). In general, the subjects in both groups displayed a higher consistency for labelling taste stimuli than flavours. No significant differences were found between the patients and controls regarding correct labelling.

Reaction time (Figure 2)

The duration of reaction time elapsing between the stimulus presentation and the verbal report showed marked inter-individual variation. On average, taste stimuli were labelled within 2–4 seconds, while flavour identification required 6–10 seconds. The longest latencies were measured at the first testing session. However, the mean reaction time for the different stimuli showed no significant difference between the two groups.

Hedonic estimates of the stimulus (Figure 3)

A wide individual variation was found for the hedonic rating of taste and flavour stimuli. However, no differences were found among the various sessions or between the two groups.

The distilled water samples scored within the range of 70–80 mm on the VAS, by both groups. The sucrose solutions in both concentrations (A and B) were considered pleasant (within the range of 60–100 mm on the VAS), whereas the other taste samples (C–F) scored lower on the VAS (within the range of 0–40 mm) and were considered repulsive. The lower concentrations of

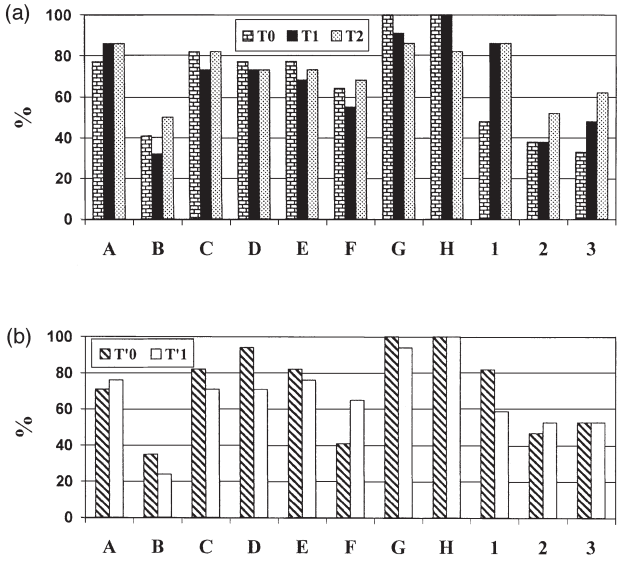

Figure 1 Mean percentage of correct verbal labelling for the various stimuli (A–H, 1–3) in (a) the experimental group in the three testing sessions and (b) the control group in the two testing sessions.

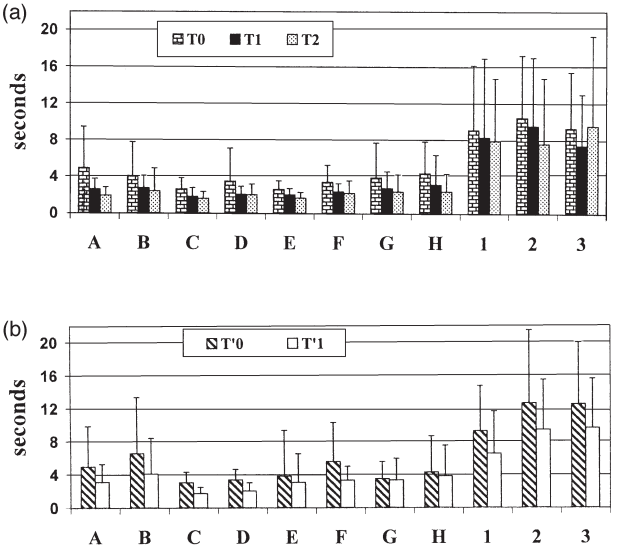

Figure 2 Mean identification time in seconds (± standard deviation) for the various stimuli (A–H, 1–3) in (a) the experimental group in the three testing sessions and (b) the control group in the two testing sessions.

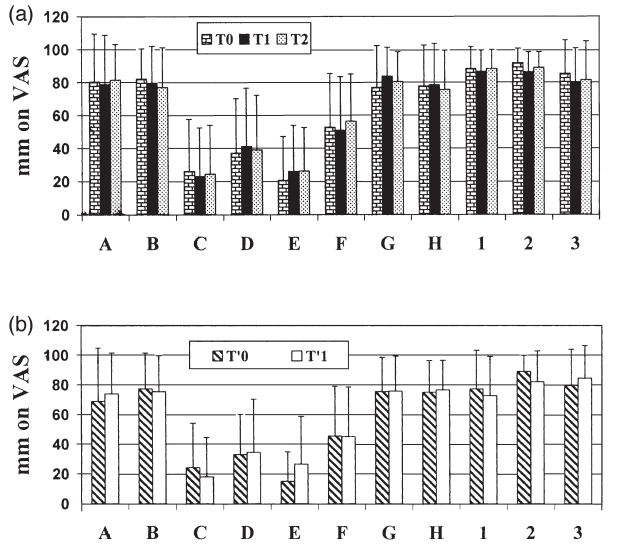

Figure 3 Mean hedonic estimate (mm) on a visual analogue scale (± standard deviation) for the various stimuli (A–H, 1–3) in (a) the experimental group in the three testing sessions and (b) the control group in the two testing sessions.

citric acid and NaCl (D and F) were more acceptable than their higher concentrations (C and E). The flavour sensations were scored as pleasant (within the range of 60–100 mm on the VAS) by the majority of the subjects.

Intensity estimates of the stimulus (Figure 4)

Once again a wide individual variation was found regarding the reported intensity of the various stimuli. However, the majority of participants in both groups were able to differentiate between the low and high concentrations of the three taste substances (sweet, sour and salty). The distilled water samples were scored as low intensity stimuli within the range of 0–30 mm on the VAS. The scores for the three flavours were of similar medium intensity, within the range of 40–60 mm on the VAS. No differences between the groups were found regarding perception of the intensity of the various stimuli.

Discussion

The reactions to taste and flavour stimuli can be determined objectively, using physiological indicators such as heart rate, blood pressure, saliva secretion, or the gusto-facial reflex (Steiner *et al.*, 1982; Bellisle, 1989). A different approach is the subjective psychophysical evaluation based on verbal description and semi-quantitative rating of the hedonics and intensity of the stimuli. Because the main requirements in the design of this study were sessions of short duration and simplicity of instructions appropriate to the situation of young patients in an orthodontic clinic, the latter approach was applied. The actual tool used in this study was the VAS, which has been used previously under similar circumstances (Steiner *et al.*, 1982; Bellisle, 1989; Matsui *et al.*, 1996; Angelili *et al.*, 2000). Indeed, the results indicate that for the majority of the subjects in both groups the reactions elicited by similar stimuli were congruous.

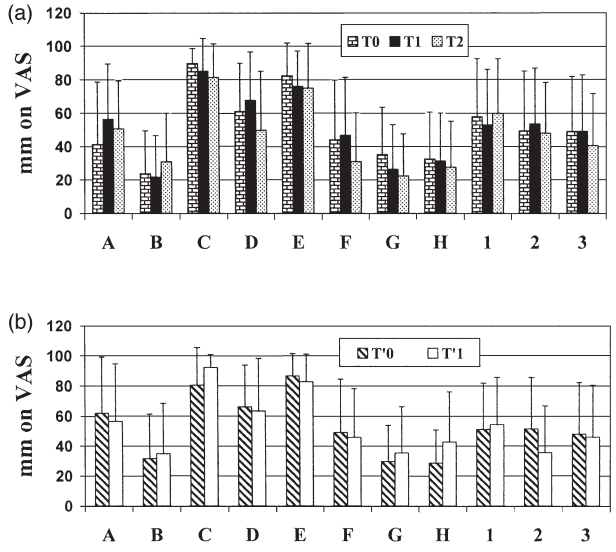

Figure 4 Mean intensity estimate (mm) on a visual analogue scale (± standard deviation) for the various stimuli (A–H, 1–3) in (a) the experimental group in the three testing sessions and (b) the control group in the two testing sessions.

The method error was established based on the study by Raben *et al.* (1995) who found an 8 per cent error in the scoring of various variables (among them also palatability) regarding food samples. In the present investigation, children for whom the intensity and palatability of identical stimuli differed by more than 7 per cent were considered inconsistent and were not included in the study.

Based on prosthetic clinical reports (Murphy, 1971; McHenry, 1992; Steas, 1997) it can be assumed that the mere presence of a removable appliance covering the palate could disturb normal oral function, including smell and taste. Opinions differ regarding the location of taste buds. Schiffman (1997) indicated that no taste buds can be found in the area covered by the URA, while others claim that some gustatory ability can be found on the border between the soft and hard palate (Nilsson, 1979). The presence of a URA also prevents contact of the tongue with the palatal rugae. This contact is considered important by some researchers (Henkin, 1970; Schiffman, 1997) for dispersing the test sample and bringing it into a more intimate contact with the taste buds. In addition, it was found that palatal coverage distorts the 'oral image' of the tested samples. The oral image of all food samples is influenced by its taste, flavour, texture, size, shape and temperature. The perception of these features may also be indirectly altered (Murphy, 1971; Murphy *et al.*, 1974). Another possible factor could be the entrapment of a part of the sample between the plate and the palate. This phenomenon can have an inhibitory (Giddon *et al.*, 1954; Duffy *et al.*, 1999) or enhancing (Kapur *et al.*, 1967) effect on the relevant senses. These smell and taste sensations can also be modulated by co-existent somatomotor stimulation from the oral cavity. Palatal coverage can modulate taste information by sensations of pain, pressure or touch, thus changing the perceived taste (Schiffman, 1997). Finally, the bulk of the URA may interfere with the usual mobility of the tongue and cheeks. This may prevent the release of flavours from the food samples and the free movement of the humid and warm air in the oral and nasal cavities, thus affecting retro-nasal olfaction (Burdach and Doty, 1987; Duffy *et al.*, 1999; Dziuk-O'Donnell, 1999).

In addition to these possible mechanical disturbances introduced by a URA, other factors may also distort the relevant sensations:

1 Late release of the self-curing acrylic monomer which can possibly alter the sensations directly, as

well as cause mucositis or allergic reactions, which indirectly affect taste (Baker *et al.*, 1988).

2 Changes in thermal conductivity in the palate, which was studied in animals (Kapur and Fischer, 1981) and humans wearing dentures (Shannon *et al.*, 1970).

3 Increased salivation reported by orthodontic patients for a period of weeks and even months (Stewart *et al.*, 1997) which may dilute the taste stimuli.

In general, however, no significant differences between patients and controls were found, indicating that a URA does not influence the patient's ability to detect and identify taste and flavour sensations. Several aspects of these clear-cut results require further analysis.

Verbal labelling

Some patients found verbal labelling of some of the samples difficult. This may originate from the following.

Low concentrations of some of the taste stimuli. An attempt was made to use above threshold concentration values for all the taste stimuli. However, there is no universal agreement as to these values. Stimulus B (0.03 M sucrose solution), which was problematic for many of the subjects, was only marginally higher than the accepted threshold for sucrose (0.02 M), possibly causing some problems in correct identification.

Age of the patients. In a previous study utilizing the same materials and methods in an adult population, a higher percentage of correct answers was obtained (Steiner *et al.*, 1993). It may be that the discrimination of taste and smell stimuli is more precise in adults than in children.

Dichotomous labelling. Only two categories of verbal identification were used: 'correct' and 'incorrect'. A more detailed scale of possibilities (such as adding that of 'near to correct') could probably have improved the results of the study in this regard.

Reaction time

The reaction time for the taste stimuli decreased consistently as the subjects learned the testing routine (Figure 2). The longer time needed for correct identification of the flavour stimuli may be caused by the physical properties of the chewing gum as opposed to the liquid taste samples. In order to obtain a satisfactory intra-oral flavour stimulus, the chewing gum had to be manipulated for a certain period of time. This time period could not be decreased significantly with subsequent tests in the patient group. However, in the controls, in contrast to the patient group, the reaction time for the flavour sample decreased at the second examination. This can be explained by the more difficult oral handling of chewing gum when a patient is wearing a removable appliance.

Hedonic evaluation

All the taste and flavour stimuli, except for the NaCl and citric acid solutions, evoked relatively high hedonic scores (60–100 on the VAS). A similar distribution of these scores for the taste stimuli was obtained in previous studies on adults (Steiner *et al.*, 1982, 1993; Steiner, 1994; Perl *et al.*, 1997). However, the hedonic evaluation of the water samples was unexpectedly high (around 75 mm on the VAS) compared with a more 'neutral' evaluation (55–59 mm on the VAS) in previous studies. It may be that the young subjects found it difficult to relate to water as a 'neutral' stimulus and found it rather refreshing and thus awarded it higher scores.

Intensity evaluation

All participants were able to clearly differentiate between the low and high concentrations of the taste stimuli. The intensity of all the flavour stimuli was equally evaluated and considered similar to the high concentration sucrose solution (A).

An attempt to compare the present results with others in the literature seems futile due to the extreme variability in the measurement methods of taste and smell, in the types and concentrations of the stimuli, in the age of the subjects and in the study design. A possible comparison can be made with the work of Shannon *et al.* (1969) who examined saliva flow from the parotid gland as an objective marker of the response to different liquid taste stimuli in patients wearing a night guard which also covered the hard palate. The solutions used were of similar composition and concentration and the participating patients (n = 40) were 17–22 years of age. The fact that the salivary flow was not affected correlates with the present study which found that the intra-oral appliance did not affect the response to taste stimuli. These findings support the present results, indicating a lack of influence of the URA on taste and flavour.

How can these results be reconciled with the taste disturbances reported in patients using full dentures? The age of the patients may play an important role, as denture wearers in most cases are elderly and a well-known phenomena in this age group is the decline in ortho-nasal and retro-nasal smell as well as in taste (Doty *et al.*, 1984; Schiffman, 1997; Duffy *et al.*, 1999; Bromley, 2000). In addition, the palatal area covered by dentures is more extensive than that covered by URA. Additional factors may play a role as well: the bulkiness of dentures, sometimes worn in both arches, may interfere with

airflow; friction between the lower denture and the tongue may affect the function of the lingual taste buds; retention requirements of the dentures may affect muscle function, thus limiting the oral manipulation of food particles in the oral cavity; the efficiency of chewing by denture wearers is diminished and once again the intimate contact between the taste molecules and taste buds is hampered (Duffy *et al.*, 1999).

It should be mentioned that the results of the present study relate only to URA. Their applicability to lower removable or fixed orthodontic appliances should be examined separately.

Conclusions

The results indicate that a URA does not interfere with the taste and flavour sensations evoked by the stimuli used in this study; this should encourage orthodontists to demand full-time wear of URA, including during meals, without fear of affecting taste and flavour sensations.

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Acknowledgements

The authors wish to thank Mr I. Einot for his help with the statistical evaluation and Dr Z. Lurie for critical review of the manuscript.

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