European Journal of Orthodontics 32 (2010) 535–541
doi:10.1093/ejo/cjp121
Advance Access Publication 27 July 2010

© The Author 2010. Published by Oxford University Press on behalf of the European Orthodontic Society.
All rights reserved. For permissions, please email: journals.permissions@oxfordjournals.org

A controlled evaluation of oral screen effects on intra-oral pressure curve characteristics

Michael Knösel*, Klaus Jung**, Gero Kinzinger***, Oskar Bauss**** and Wilfried Engelke*****

Departments of *Orthodontics, **Medical Statistics and *****Maxillofacial Surgery, University of Göttingen, Göttingen, ***Department of Orthodontics, University of Saarland, Homburg/Saar, ****University of Hannover, and Private Practice, Hannover, Germany

Correspondence to: Dr Michael Knösel, Department of Orthodontics, Center of Dentistry, University of Göttingen, Robert-Koch-Strasse 40, 37099 Göttingen, Germany. E-mail: mknoesel@yahoo.de

SUMMARY The purpose of this study was to quantify the impact of oral screen (OS) application on intra-oral pressure characteristics in three malocclusion groups.

Fifty-six randomly recruited participants (26 males and 30 females) who met the inclusion criteria of either an Angle Class I occlusal relationships or Angle Class II1 or II2 malocclusions, were assigned by dentition to group I (n = 31), group II1 (n = 12), or group II2 (n = 13). Two 3 minute periods of intra-oral pressure monitoring were conducted on each participant, using two different oral end fittings connected to a piezo-resistive relative pressure sensor: (1) a flexible OS and (2) a small-dimensioned air-permeable end cap (EC), which was placed laterally in the premolar region, thus recording intra-oral pressure independent of the influence of the OS. Pressure curve characteristics for both periods and between the malocclusion groups were evaluated with reference to the frequency of swallowing peaks, duration, and altitude of negative pressure plateau phases and the area under the pressure curve. Statistical analysis was undertaken using analysis of variance (ANOVA), the Wilcoxon Mann–Whitney test, and spearman correlation coefficient.

A median number of two peaks (median height –20.9 mbar) and three plateau phases (median height of –2.3 mbar) may be regarded as normative for normal occlusion subjects during a 3 minute period, at rest. OS application raised the median average duration and height of intra-oral negative pressure plateau phases in the II1 subjects, exceeding those of group I, but less than the plateau duration in group II2. Median peak heights were distinctively lower in groups I and II1 during OS application.

It is concluded that additional training for extension of intra-oral pressure phases may be a promising approach to pre-orthodontic Class II division 1 treatment.

Introduction

Incisor position and the formation of the dentition can be seen as the product of an equilibrium of forces exerted on the teeth by the dentition (Proffit, 1978). The equilibrium that surrounds the dentition primarily comprises opposing forces from buccal soft tissues (lips and cheeks) and the tongue (Proffit, 1978; Thüer *et al.*, 1999).

The formation of malocclusions is often correlated with altered tension of the soft tissues (Thüer and Ingervall, 1986; Mew, 2004) and may partly be attributed to a disturbance in the environmental force equilibrium. For example, open bite situations and proclined incisors are positively correlated with hypotonic masticatory (Lowe, 1980) or mimic (Lowe and Takada, 1984) muscles or lowered lip strength (Thüer and Ingervall, 1986) and may therefore be interpreted as a clinically manifest effect of a disturbed equilibrium of forces (Proffit, 1978).

However, these previous studies on intra-oral forces mostly do not take into consideration negative intra-oral pressure as a contributory factor and that has been described by Fröhlich *et al.* (1991). A remarkable result of their study was the negative intra-oral pressure recorded in the upper and lower incisor and upper molar region that, until then, had not been detected because previous measurement methods, including strain gauge transducers, were unable to record negative pressures (Proffit, 1978).

The use of oral screens (OSs) is a common feature of early orthodontic treatment of proclined incisors (Owman-Moll and Ingervall, 1984) and previous research provided evidence of OS shields exerting an influence on the equilibrium of environmental forces, e.g. by the early prevention of lip-sucking habits (Prasad and Utreja, 2005). OS therapy effects on incisor position are often attributed to changes in muscular activity after incorporation of OSs (Tallgren *et al.*, 1998), whereas other authors state that OS therapy does not contribute to a normalization of lip function, despite an increase in maximum lip strength (Owman-Moll and Ingervall, 1984), suggesting that OS effects may have a purely mechanical nature. As OSs are stabilized by the orbicularis oris muscle, it may be hypothesized that the individual variation in its tension

at rest, typical for different types of malocclusion (Lowe and Takada, 1984), may determine the magnitudes of OS effects.

Thüer and Ingervall (1990) recorded a temporary increase in lip strength by muscle exercises with OSs, which, however, did not result in a significant increase in lip pressure, which they concluded to be the reason for relapses in OS effects achieved after the end of treatment.

In a previous study on dummy-sucking children, Lindner and Hellsing (1991) recorded both intra-oral air pressure as well as cheek and lip pressure. They concluded, from the correlation between the negative atmospheric pressure and the positive soft tissue forces, that circumoral muscles are particularly active during dummy sucking. However, until now, it remains unclear whether, or to what extent, OS effects can be ascribed to active neuromuscular soft tissue forces alone or also to existing physical intra-oral pressure levels. If the latter holds true, the problem of relapse in achieved therapy effects (Thüer and Ingervall, 1990) may be addressed by modification of the use of OSs, in order to influence tongue position and functional disturbance during respiration, including conscious intra-oral generation of negative pressures similar to exercises successfully applied in therapy for snoring (Engelke *et al.*, 2006).

OSs are commonly used in Angle Class II division 1 malocclusions, which are positively correlated with hypotonic mimic muscles (i.e. orbicularis oris, buccinator, mentalis; Lowe and Takada, 1984) and in which pressure levels approximating atmospheric pressure may be assumed, due to a gap in the upper and lower dental arch and lip formation. In contrast, in Class II division 2 situations, higher negative pressure levels may be expected (Lowe and Takada, 1984). These two malocclusions may therefore be adequate for evaluating whether OS effects are equal in subjects with suspected different negative pressure levels and differently developed mimic muscles.

The detection of OS- and malocclusion-related changes in intra-oral negative pressure levels would provide the basis for the development of treatment approaches to achieve a permanent normalization of possible imbalances in the intra-oral force equilibrium (Proffit, 1978; Engelke *et al.*, 2006).

It was the aim of the present study to quantify the contribution of negative atmospheric pressure with an OS application in Angle Class II division 1 and division 2 malocclusion groups compared with an Angle Class I control group. The following null hypotheses were tested:

There are no significant differences in frequency and of swallowing, duration, and magnitude of negative pressure phases (1) between intra-individual measurements with and without OSs and (2) between a normal occlusion group, a Class II division 1 group, and a Class II division 2 group.

Subjects and methods

The study was the approved by the local Ethics Committee of Georg-August-Universität Göttingen (No.5/7/08).

In order to perform a controlled evaluation of the OS effect, 56 randomly selected participants (26 males and 30 females, mean age 28.4 years; SD 5.2 years) with no orthodontic treatment history were assigned, according to their dentition, to either of three groups: group I (n = 31, 14 males and 17 females) normal occlusal relationship, as characterized by an Angle Class I molar and canine relationship, and interdigitated and aligned interincisal relationships. Exclusion criteria were decayed or missing teeth and obstructed airways. Therefore, an anamnestic and clinical evaluation was performed on each participant for clarification of the presence or absence of obstructed nasal airways. Group II1 comprised 12 subjects (eight males and four females) who met the inclusion criterion of an Angle Class II division 1 dental relationship, and group II2 13 subjects (four males and nine females), with Angle Class II division 2 malocclusions.

In order to control the OS effects, two 3 minute periods of intra-oral pressure monitoring with a hand-held digital precision measuring instrument (GMH3050; Greisinger; Regenstauf, Germany) were conducted on each participant, using two different oral end fittings: for the first recording a flexible OS, and, for the second recording, a standardized, small-dimensioned air-permeable end cap (EC; Figure 1a). Both were fitted to a flexible polyvinyl chloride tube (inside diameter: 4 mm) and connected to a piezo-resistive relative pressure sensor (GMSD 350 MR; Greisinger) capable of recording pressures in a measuring range of 500 mbar relative (rel.) and with a resolution of 0.1 mbar rel. (peak value memory: logging of pressure peaks >10 ms; peak-detect (>100 measurements/s). In the first instance, the subjects were instructed to hold the OS gently with the lips, but otherwise to breathe and swallow as normal during the 3 minute pressure monitoring period (groups I-OS, II1-OS, and II2-OS). During a second 3 minute period, the OS was replaced by the EC located laterally in the premolar region, thereby recording intra-oral pressures independent of a possible OS influence (groups I-EC, II1-EC, and II2-EC). The lips were gently closed during this interval. All measurements were performed at the chair-side in a natural head position (Archer and Vig, 1985). The occurrence of very small time delays in registering intra-oral pressure was acceptable because long-term effects and not short-term activities were within the scope of the measurements (Proffit, 1978).

The data for both periods were processed using the software GSOFT3050 (Greisinger) and evaluated with regard to the frequency and magnitude of swallowing peaks, and frequency, duration, and altitude of negative pressure plateau phases, as well as the area under the pressure curves. Example diagrams for both periods are given in Figure 1b. The differences between plateau phases and pressure peaks were evaluated. The former included a pressure oscillation of less than 5 mbar and a duration of at least 5 seconds, in order to distinguish plateau phases from the duration of normal swallowing. The latter was defined as a change in

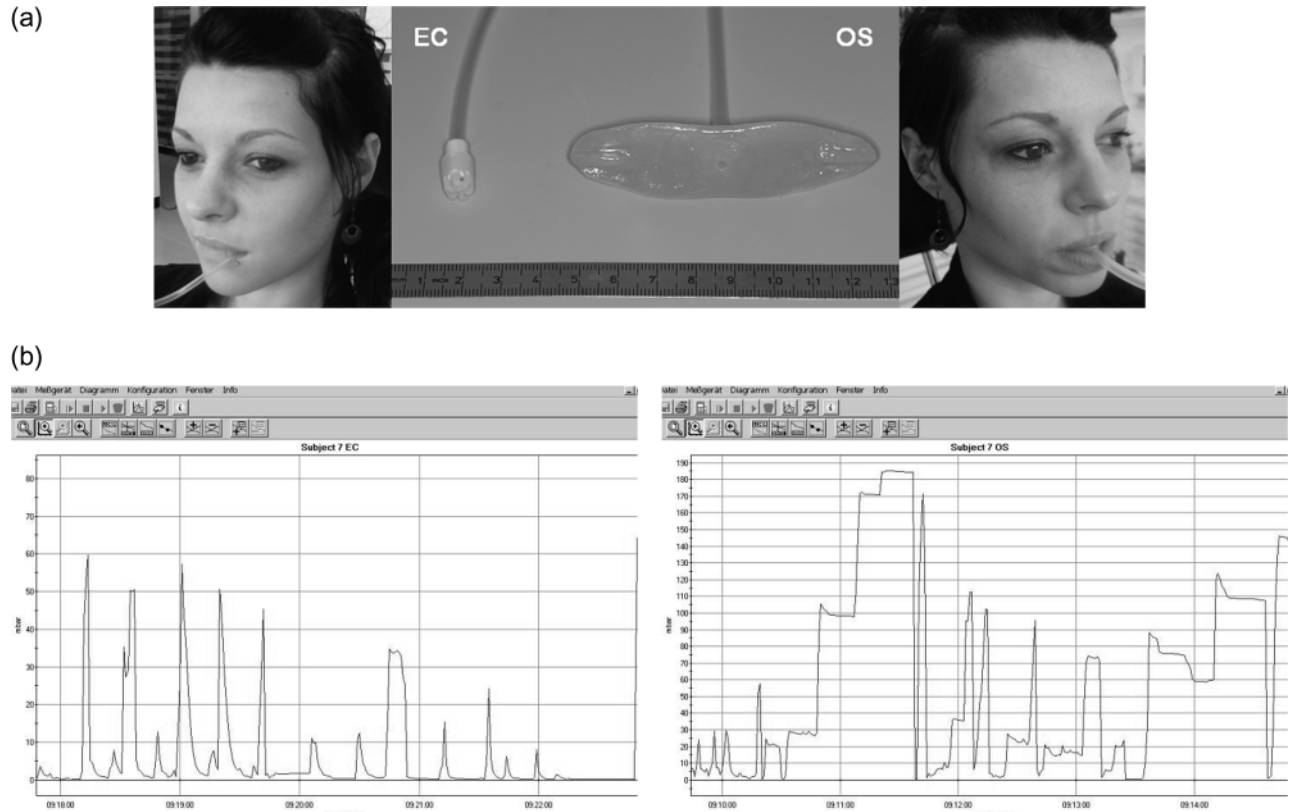

Figure 1 (a) An end cap (EC, left) with small dimensions that is air permeable and a flexible oral screens (OS, right) were used as oral end fittings. (b). Example diagrams for one subject's measurements with an EC (left) and with an OS (right). Pressure values are negative (−mbar).

pressure of 5 or more mbar in less than 1 second and a second change (decrease) within 5 seconds.

Statistical analysis

For evaluating the influence of malocclusion and the method of measurement (OS or EC), as well as possible interactions between these two variables on the distinct pressure curve parameters, a non-parametric longitudinal analysis of variance (ANOVA) model was applied (Brunner *et al.*, 2002). In addition, pairwise comparisons between the different subgroups were performed using the Wilcoxon and Mann–Whitney test.

Correlations between the number of peaks (plateaus) and the average peak (plateau) heights were assessed with Spearman's correlation coefficient ρ and by the relevant test for the null hypothesis.The significance level was set to α = 5 per cent for all tests.

Descriptive statistics and correlation coefficients were calculated with the software R 2.6 (www.r-project.org). The longitudinal ANOVA was carried out using SAS 9.1 (SAS Institute, Cary, North California, USA).

Error analysis

The error of the measurement was evaluated in a prior series of eight time-repeated measurements performed on two subjects using the EC fitting with slightly opened lips, i.e. at an atmospheric pressure level. Only very minor deviations were observed between the single measurements with reference to frequencies and magnitudes of peaks and plateau stages.

Results

Malocclusion and OS-related effects

The graphical representations of the distinct pressure curve parameter distributions induced by OS application or malocclusion are depicted in Figures 2–4. A significant difference was detected for the average plateau height in group II2 (OS) compared with the other subgroups (Figure 3b) using ANOVA (P = 0.02, Table 1) and subsequent pairwise comparisons (Table 2). Significant differences were also confirmed for the area under the pressure curve (Table 2). Median values, as well as lower and upper quartiles for the distinct parameters, are listed in Table 3.

Descriptive statistics

While ANOVA detected some significant effects for average plateau height and the area under the curve, Figures 2–4 show that there were clear differences in the dispersion of various effects in the different subgroups depending on the use of the OS. The range and inter-quartile range for all parameters tested was during OS application compared with

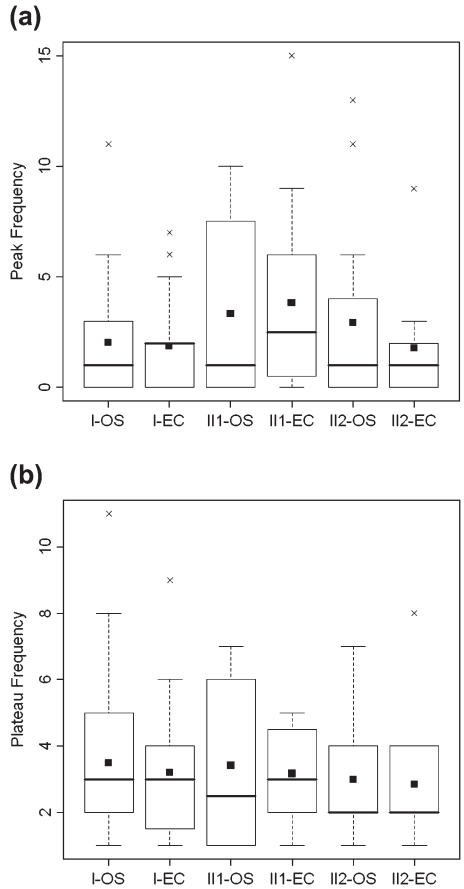

Figure 2 Distribution of peak (a) and plateau (b) frequencies in the three groups [Class I, Class II division 1, and class II division 2], during oral screen (OS) and end cap (EC) periods (quadrates represent mean values).

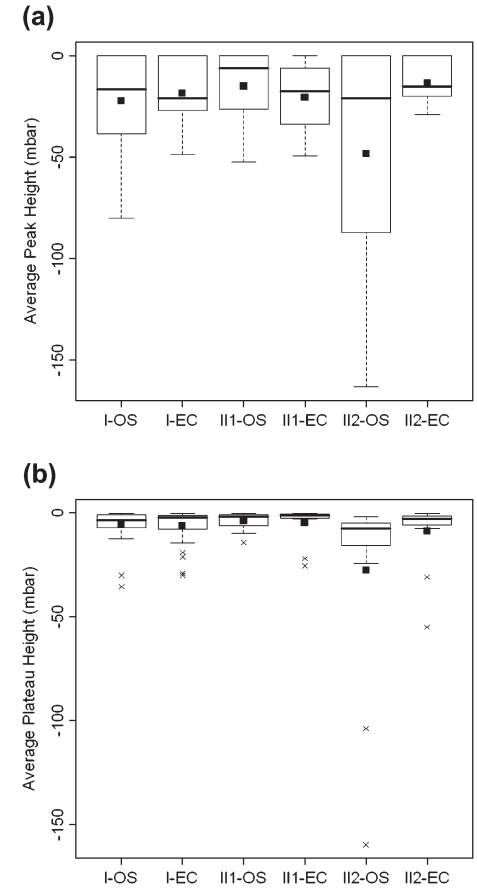

Figure 3 Distribution of average peak (a) and plateau (b) heights in the three groups [Class I, Class II division 1, and class II division 2], during oral screen (OS) and end cap (EC) periods (quadrates represent mean values).

EC measurements. This finding holds for almost all malocclusion/OS configurations (Table 4).

In detail, OS application mostly resulted in higher variances of peak and plateau frequencies, except for group II2 plateau frequencies (Figure 2a and b). Average median peak heights decreased in group II1-OS during OS application. Average median plateau heights were almost equal for groups I-OS and I-EC, and II1-OS and II1-EC, but higher in II2-OS (Figure 3b). Average median plateau duration was longer for II1-OS compared with II1-EC, but equal for II2-OS versus II2-EC and for I-OS versus I-EC (Figure 4).

Correlation between numbers and average height of peaks (plateaus)

In most subgroups, the peak frequency was significantly positively correlated with the average peak height. However, only in subgroup II2-OS, was there a significant correlation between plateau frequency and average plateau height (Table 5).

Table 1 Longitudinal analysis of variance for the detection of malocclusion group, method (oral shield or end cap), and interaction effects between malocclusion groups and method.

Parameter	*P* (group effect)	*P* (method effect)	*P* (interaction effect)
Peak frequency	0.75	0.58	0.71
Plateau frequency	0.79	0.93	0.89
Average peak height	0.88	0.72	0.23
Average plateau height	0.02	0.08	0.02
Average plateau duration	0.85	0.74	0.57
Area under the pressure curve	0.07	0.05	0.07

Discussion

There is some evidence that OS effects on incisor position may be due to only mechanical pressure on the upper incisors (Owman-Moll and Ingervall, 1984; Tallgren *et al.*, 1998). However, as an Angle Class II division 1 formation is, in many cases, assumed to be induced by hypotonic mimic muscles and stopped by subsequent open mouth situations (Lowe, 1980; Lowe and Takada, 1984), implicating low-negative intra-oral pressure at the level of environmental atmospheric pressure, it may be postulated

Table 2 Pairwise comparisons of average plateau height, peak frequency, average plateau duration, plateau frequency, average peak height, and area under the pressure curve for the different subgroups of malocclusions, Classes, and methods [oral shield (OS) or end cap (EC)].

Comparison of groups	*P* (Wilcoxon)					
	Peak frequency	Plateau frequency	Average peak height	Average plateau height	Average plateau duration	Area under pressure curve
I-OS versus I-EC	0.95	0.67	0.55	0.52	0.89	0.49
I-OS versus II1-OS	0.82	0.73	0.37	0.54	0.99	0.57
I-OS versus II1-EC	0.29	0.93	0.95	0.26	0.33	0.30
I-OS versus II2-OS	0.88	0.62	0.44	< 0.01	0.88	< 0.01
I-OS versus II2-EC	0.71	0.50	0.42	1.00	0.86	0.76
I-EC versus II1-OS	0.79	0.97	0.37	0.39	0.91	0.70
I-EC versus II1-EC	0.27	0.84	0.87	0.15	0.26	0.30
I-EC versus II2-OS	0.70	0.80	0.44	0.01	0.93	< 0.01
I-EC versus II2-EC	0.63	0.54	0.23	0.84	0.71	0.72
II1-OS versus II1-EC	0.76	0.62	0.48	0.78	0.31	0.85
II1-OS versus II2-OS	1.00	0.93	0.27	< 0.01	0.89	0.01
II1-OS versus II2-EC	0.82	0.91	0.84	0.41	0.96	0.69
II1-EC versus II2-OS	0.40	0.66	0.58	< 0.01	0.64	< 0.01
II1-EC versus II2-EC	0.27	0.39	0.38	0.13	0.26	0.19
II2-OS versus II2-EC	0.55	1.00	0.12	0.03	0.74	0.03

Table 3 Median value (lower and upper quartile) of the distinct curve characteristics with oral screen (OS) or end cap (EC) in groups I, II1, and II2.

Parameter	Group					
	I-OS	I-EC	II1-OS	II1-EC	II2-OS	II2-EC
Peak frequency (*n*)	1.0 (0.0, 3.0)	2.0 (0.0, 2.0)	1.0 (0.0, 7.2)	2.5 (0.8, 5.5)	1.0 (0.0, 4.0)	1.0 (0.0, 2.0)
Plateau frequency (*n*)	3.0 (2.0, 5.0)	3.0 (1.5, 4.0)	2.5 (1.0, 6.0)	3.0 (2.0, 4.2)	2.0 (2.0, 4.0)	2.0 (2.0, 4.0)
Average peak height (mbar)	-16.6 (-38.5, 0.0)	-20.9 (-27.1, 0.0)	-6.2 (-24.6, 0.0)	-17.6 (-30.8, -9.4)	-21.1 (-87.3, 0.0)	-15.2 (-20.0, 0.0)
Average plateau height (mbar)	-3.6 (-7.2, -0.9)	-2.3 (-7.8, -1.4)	-1.9 (-6.2, -1.0)	-1.2 (-2.4, -0.7)	-7.7 (-15.7, -4.8)	-3.1 (-5.8, -1.5)
Average plateau duration (second)	55.3 (30.1, 86.0)	54.0 (37.5, 127.0)	70.7 (18.4, 174.0)	38.0 (26.9, 85.1)	82.0 (27.0, 87.0)	82.0 (39.8, 86.5)
Area under the curve (second × mbar)	612.4 (304.6, 1504.0)	578.6 (358.1, 1117.0)	664.0 (176.8, 1437.0)	366.4 (249.1, 580.9)	2599.0 (885.9, 3300.0)	558.2 (379.4, 1134.0)

that orthodontic strategies should also address the normalization of these factors.

The formation of intra-oral pressure can be defined as the difference between the atmospheric extra-oral environment and intra-oral functional spaces, as formed between a closed capsular matrix (Moss and Salentijn, 1969) consisting of buccal soft tissues, tongue, and teeth. Intra-oral pressure curve plateaus represent a status of oral negative pressure with equilibrium forces from the lingual and vestibular directions. The persistence of these pressure plateaux can be explained by a passive lowering of the tongue after swallowing, as earlier described by Eckert-Möbius (1953) and Fränkel (1967) who considered the occurrence of a subpalatal space after deglutition as part of normal physiology. Plateau phases may therefore be hypothetically regarded as being in a state of equilibrium. Accordingly, plateau heights may indicate the magnitude of therapeutic forces: the greater the forces, the higher the effect on soft tissues and teeth formation. Plateau duration in the present study addresses the question of whether OSs may enhance the ability of mouth closure, i.e. the impact of the OS on the generation of intra-oral negative pressures. This may be of special interest in Angle Class II division 1 subjects, which are positively correlated with hypotonic muscles and open mouth situations, indicating an equilibrium different from that of Angle Class I or Class II division 2 subjects (Moss and Salentijn, 1969; Proffit, 1978).

With regard to the control groups, OS-I and EC-I, the 1–2.5 peaks at average peak height between −16.6 (OS) and

Table 4 Ranges and inter-quartile ranges of the different parameters for all malocclusion groups during oral screen (OS) and end cap (EC) periods.

Parameter	Group	Range		Inter-quartile range	
		OS	EC	OS	EC
Peak frequency (*n*)	I	11.0	7.0	3.0	2.0
	II1	10.0	15.0	7.3	4.8
	II2	13.0	9.0	4.0	2.0
Plateau frequency (*n*)	I	10.0	8.0	3.0	2.5
	II1	6.0	4.0	5.0	2.3
	II2	6.0	7.0	2.0	2.0
Average peak height (mbar)	I	80.2	48.8	38.5	27.2
	II1	52.4	49.4	24.7	21.4
	II2	163.2	29.3	87.3	20
Average plateau height (mbar)	I	35.3	30.0	6.3	6.4
	II1	14.2	25.2	5.2	1.7
	II2	157.8	54.8	10.9	4.3
Average plateau duration (second)	I	172.7	162.1	55.9	89.5
	II1	162.6	162.2	155.6	58.2
	II2	164.2	162.5	60.0	46.7

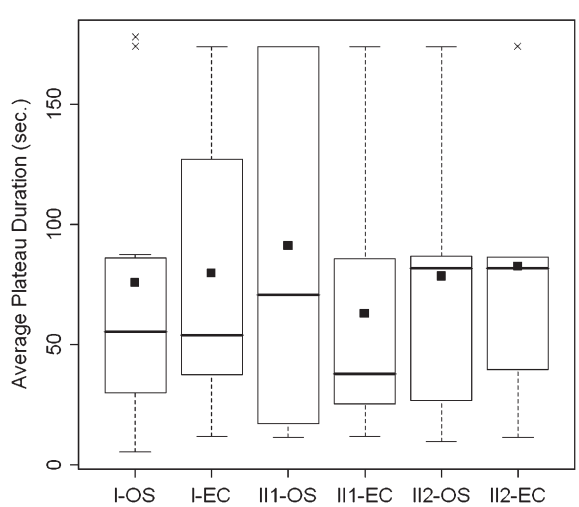

Figure 4 Distribution of average plateau duration in groups Class I, Class II division 1, and Class II division 2, during oral screen (OS) and end cap (EC) periods (quadrates represent mean values).

−20.9 (EC) mbar can be regarded as normative for normal occlusion subjects. Furthermore, two to three plateau phases at a median height of −2.3 (EC) to −3.6 (OS) mbar during the 3 minute period may be regarded as normative for all subjects (Table 3).

Using pairwise comparisons, the null hypotheses of (1) no significant differences between intra-individual measurements with and without OSs and also (2) between the different malocclusion groups were rejected only for the plateau height in group II2. However, descriptive statistics revealed that the median duration of plateau phases in group II1-OS was almost doubled compared with EC measurements (Figure 4 and Table 3) and the median negative pressure plateau height slightly increases by 0.7 mbar, whereas peak frequencies and heights were at the same time lowered, the latter from an average of 17.6 mbar (EC) to 6.2 mbar (OS), similar to the slight decrease in median peak heights in group I and in contrast to an increase in the OS-II2 group. This finding seems plausible against the background of the common feature of hypotonic mimic muscles in Angle Class II division 1 subjects and given the fact that OSs are usually stabilized by the tension of the lips and the peri-oral muscles. It also emphasizes the value of the recommendation to train lip closure during the application of OSs, in order to enhance their efficiency (Fränkel, 1967). As there was no significant difference regarding average plateau height between II1-OS and I-OS, compared with group OS-II2 (Table 2), it may be concluded that subjects belonging to the latter group are able to hold the OS more efficiently than those in the other groups. This hypothesis is supported by the findings of Lowe and Takada (1984) who found no significant differences between the orbicularis oris muscle strength in Angle Class I and Class II division 1 subjects.

Median plateau duration after OS insertion in group II1-OS exceeded that of group I (54 seconds), which seemed to be unaffected by OS application with regard to plateau duration, but did not reach the plateau duration of group II2 (82 seconds), which was also not affected by OS application (Table 3). Moreover, the area under the pressure curve in group II1 was raised during OS application from

Table 5 Correlations between peak frequency and average peak height and between plateau frequency and average plateau height with the end cap (EC) and oral screen (OS).

Parameter	Method	Group I, *n* = 31		Group II division 1, *n* = 12		Group II division 2, *n* = 13	
		ρ	*P*	ρ	*P*	ρ	*P*
Peak	EC	0.65	<0.01	0.59	0.04	0.70	<0.01
	OS	0.52	<0.01	0.91	<0.01	0.51	0.08
Plateau	EC	−0.10	0.59	0.09	0.78	−0.20	0.51
	OS	0.26	0.17	0.57	0.05	0.65	0.02

366.4 to 664 mbar × seconds (Table 3). Although this was not statistically significant, it is, however, more than likely that changes of such magnitude are clinically relevant, as they have the potential to tip teeth, if they are continuously applied. These findings indicate that OS effects may be partly attributed to individual intra-oral pressure levels and that OS therapy seems to have the potential to alter intra-oral pressure levels. The median average height of the plateau phases declined for both the OS and the EC measurements in the order of groups II2 > I > II1. This finding may be interesting with regard to the theory of the equilibrium of forces, according to which tooth formation may be regarded as the product of forces exerted by the soft tissues and also the fact of negative intra-oral pressures. From this perspective, it is remarkable that median average negative pressure plateau heights in group II1-OS were higher than in the II1-EC group (Table 3). As the results indicate a variation in intra-oral equilibrium depending on the malocclusion, further nasal breathing exercises and training of the tongue reposition manoeuvre (Engelke *et al.*, 2006) to achieve normalization of disturbed intra-oral force equilibria may be promising as a pre-orthodontic strategy, in order to potentially facilitate orthodontic therapy.

The subjects belonging to the various malocclusion groups reacted differently to OS incorporation. The impact of OS application subsumed the interactions between direct negative intra-oral pressure effects and positive soft tissue force effects. Because of the contracting characteristics of the circularly arranged fibres of orbicularis oris muscle, the direction of lip pressure forces is parallel to the anterior teeth axes and perpendicular to the occlusal plane, whereas forces created by negative intra-oral pressures act parallel to the occlusal plane. This explains the findings of Thüer and Ingervall (1990) who reported a maintenance of lip pressures on incisors, despite an increase in orbicularis oris muscle strength.

It may therefore be hypothesized that, with regard to the long-term stability of the OS effects achieved, the use of OSs may be more efficient if they are accompanied by additional training of the maintenance of intra-oral pressure phases (Engelke *et al.*, 2006), instead of increasing lip strength.

The present research has a limitation in the relatively small sample size and, in common with all studies on the characteristics of intra-oral pressure, the fact that variation in spontaneous swallowing may cause accidental errors to intra-oral pressure recordings. Further research will integrate intra-oral pressure on larger samples and also include magnetic resonance imaging in order to gain a deeper understanding of coherences between negative intra-oral pressures and soft tissue activities.

Conclusions

1. A significant correlation between intra-oral pressure curve characteristics and malocclusion was corroborated for the pressure plateau duration in Angle Class II division 2 subjects.
2. OS application raises median average duration and average height of intra-oral pressure plateau phases in Angle Class II division 1 subjects.
3. Additional training for extension of intra-oral pressure phases may be a promising approach to pre-orthodontic Class II division 1 treatment and should be corroborated in further studies.

References

Archer S Y, Vig P S 1985 Effects of head position on intraoral pressures in Class I and Class II adults. American Journal of Orthodontics 87: 311–318

Brunner E, Domhof S, Langer F 2002 Nonparametric analysis of longitudinal data in factorial experiments. Wiley, New York

Eckert-Möbius A 1953 Die Bedeutung der Zunge für die Nasen- und Mundatmung. Fortschritte des Kieferorthopädie 14: 229–239

Engelke W, Mendoza M, Repetto G 2006 Preliminary radiographic observations of the tongue-repositioning manoeuvre. European Journal of Orthodontics 28: 618–623

Fränkel R 1967 Die Dynamik des interokklusalen Unterdruckes. Deutsche Zahnärztliche Zeitung 22: 282–290

Fröhlich K, Thüer U, Ingervall B 1991 Pressure from the tongue on the teeth in young adults. Angle Orthodontist 61: 17–24

Lindner A, Hellsing E 1991 Cheek and lip pressure against maxillary dental arch during dummy sucking. European Journal of Orthodontics 13: 362–366

Lowe A A 1980 Correlations between orofacial muscle activity and craniofacial morphology in a sample of control and anterior open-bite subjects. American Journal of Orthodontics 78: 89–98

Lowe A A, Takada K 1984 Associations between anterior temporal, masseter, and orbicularis oris muscle activity and craniofacial morphology in children. American Journal of Orthodontics 86: 319–330

Mew J R 2004 The postural basis of malocclusion: a philosophical overview. American Journal of Orthodontics and Dentofacial Orthopedics 126: 729–738

Moss M L, Salentijn L 1969 The capsular matrix. American Journal of Orthodontics 56: 474–490

Owman-Moll P, Ingervall B 1984 Effect of oral screen treatment on dentition, lip morphology, and function in children with incompetent lips. American Journal of Orthodontics 85: 37–46

Prasad V N, Utreja A K 2005 An oral screen for early intervention in lower-lip-sucking habits. Journal of Clinical Orthodontics 39: 97–100

Proffit W R 1978 Equilibrium theory revisited: factors influencing position of the teeth. Angle Orthodontist 48: 175–186

Tallgren A, Christiansen R L, Ash Jr M, Miller R L 1998 Effects of a myofunctional appliance on orofacial muscle activity and structures. Angle Orthodontist 68: 249–258

Thüer U, Ingervall B 1986 Pressure from the lips on the teeth and malocclusion. American Journal of Orthodontics and Dentofacial Orthopedics 90: 234–242

Thüer U, Ingervall B 1990 Effect of muscle exercise with an oral screen on lip function. European Journal of Orthodontics 12: 198–208

Thüer U, Sieber R, Ingervall B 1999 Cheek and tongue pressures in the molar areas and the atmospheric pressure in the palatal vault in young adults. European Journal of Orthodontics 21: 299–309