Lip adaptation to simulated dental arch expansion. Part 2: One week of simulated expansion

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Dental arch crowding is often relieved by expanding the dental arch, either actively (by applying forces directly to the teeth) or passively (by removing the forces of the lip and cheek from the teeth). Long-term postretention studies of cases treated primarily by active expansion demonstrate poor stability of lower incisor alignment when compared with other methods of treatment.[1-9] Although passive expansion treatment appears to improve stability, the extent of improvement that can be expected has not been well defined.[10-12]

The soft tissues of the oral cavity may contribute to this postorthodontic instability. An equilibrium of resting forces from these tissues (forces from the lips and cheek counterbalanced by forces from the tongue) appears to play a role in determining the position of the teeth.[13] Disruptions of this equilibrium result in tooth movement. For example, when pressure from the lips or cheeks is removed, the teeth will move labially.[14-16] Expanding the dental arch to relieve crowding is accomplished by moving the teeth toward the lips and cheeks. This movement usually results in an increase in pressure on the teeth from the lips.[17,18] Unless tongue pressure also increases or lip pressure eventually decreases (as the lips adapt to the new position of the teeth), this movement of the teeth toward the lips would be characterized by instability.

Passive expansion proponents speculate that holding the lips and cheeks away from the teeth not only allows the teeth to move labially, it also retrains the muscles, resulting in adaptation to

Abstract

An increase in resting lip pressure and the resulting disruption of the intraoral pressure equilibrium may be responsible for the poor stability found with orthodontically expanded dentitions. Passive expansion strategies seek improved stability by altering lip pressure, thus creating a new equilibrium. One of these strategies has been shown to alter pressure favorably. However, pressure changes associated with conventional expansion need to be studied before conclusions regarding the superiority of passive expansion can be drawn. The purpose of this study was to examine lip pressure changes after 1 week of simulated conventional expansion. Twenty-two subjects agreed to wear a mandibular expansion-simulating stent full-time for 1 week. Resting pressure was measured in the midline and right canine areas. Midline lip pressure decreased significantly after 1 week while pressure in the canine area did not change significantly. This finding suggests an adaptive response that varies according to anatomic location.

Key Words

Lip pressure • Adaptation • Dental arch expansion

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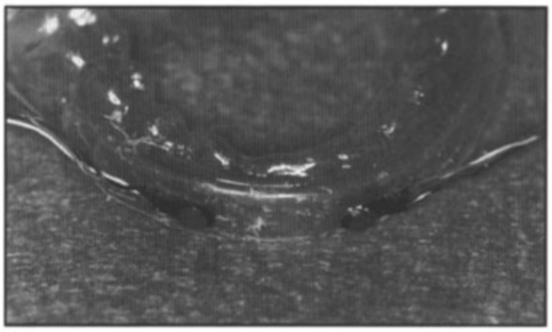

Figure 1

Figure 1
An expansion-simulating stent with diaphragm transducers attached at the midline and right canine areas.

Table 1
Age & sex distribution of subjects in the study

Sex	N	Mean age (years)
Males	10	22.2
Females	12	24.2
Total	22	23.3

the expanded dentition and a long-term reduction in pressure.[14] In this way a new equilibrium could be established and stability could be improved.

Researchers have examined the adaptability of the oral soft tissues to both active and passive expansion. Soo and Moore studied lip adaptability in 10 children who underwent lip bumper therapy (a passive expansion appliance) for 8 months.[19] Lip pressure at the midline increased at one month, then decreased to below pretreatment levels at the end of the experimental period. At the canine area, a gradual decrease in lip pressure was observed. These pressure changes occurred even as the teeth moved labially. McNulty et al.[20] studied lip adaptation by recording changes in resting lip pressure secondary to alterations in prosthetic incisor position (no passive expansion strategy was employed) in five subjects for 1 week. Subjects reacted to incisor protrusion either by an initial increase in lip pressure followed by a reduction to the original level or by erratic responses that lacked a clear-cut pattern of adaptation. Both of these studies give evidence to support the concept that the lips can adapt to an expanded dentition. This adaptation is seen in the return of lip pressure to levels near those registered before tooth movement. The study by Soo et. al. showed changes secondary to passive expansion.[19] Unfortunately, we cannot determine whether this change indicates that passive expansion improves lip adaptation, and thus possibly improves stability, because we do not have enough information about adaptation (or the lack of it) secondary to active expansion. The study by McNulty et al. offers evidence that for some subjects adaptation may occur after actively repositioning the teeth to a more labial position, but the study size was so small that definite conclusions are difficult to draw.[20]

The purpose of this study was to examine the adaptability of the lower lip to simulated mandibular dental arch expansion after 1 week.

Materials and methods

Sample selection

Twenty-two subjects (10 males and 12 females, mean age = 23.3 years ± 1.9 S.D.) were selected for the study (Table 1) according to the following criteria: good health (ASA I or II), with no craniofacial anomalies or reported speech impairments; not under any pharmaceutical therapy that might influence muscle tone; no orthodontic treatment within the past 5 years; no evidence of dental or periodontal diseases; Class I skeletal and dental relationship; and, no habits reported that could affect lip pressure. Because adaptive changes over time were being examined, the pretreatment measurements served as controls. A University of Kentucky approved informed consent form was reviewed with and signed by each subject.

Stent fabrication

Mandibular impressions were taken and stone models were made. A Biostar machine (Great Lake Orthodontics, Tonawanda, NY) was used to form thermal polyvinyl plastic stents (Tru-Tain Inc, Rochester, Minn) over the stone models. Three stents were constructed for each subject. The first was formed directly over the stone model. Two Entran EPL6 flatline pressure transducers (diaphragm-type transducers purchased from Entran Devices, Fairfield, NJ) were glued directly onto the stent in the approximate center of the clinical crowns of the right canine and in the midline. This stent was used to measure lip pressure as close to the teeth as possible. The second and third stents were formed to simulate approximately 2.5 mm of labial movement or dental expansion. One of these stents was prepared for the subject to wear full-time. The other carried two diaphragm transducers (same positions as stent #1) and was used to measure lip pressure against the simulated expansion (Figure 1).

Lip pressure tests

Each subject was seated and his or her intraoral temperature was recorded using a digital

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themometer placed in the mandibular buccal vestibule between the right canine and the midline. The transducers were calibrated as described previously.[21] The nonexpanded stent carrying the diaphragm-type transducers was placed intraorally. The subject was asked to relax his or her lips and the voltage registered from the transducers when lips were at rest (noted as "lip-on") was recorded for at least 10 seconds. The lips were held away from the teeth while lip seal was maintained and a 10-second recording ("lip-off") was accomplished. Lip-on and lip-off recordings were repeated at least twice to allow familiarization with the measuring devices. This first stent was then removed. Lip pressure was then measured using the expansion-simulating stent in the same manner. After completion of this testing session, the subject was asked to wear an expansion-simulating stent (with no transducers) full-time for 1 week (except when eating, performing oral hygiene procedures, or engaging in active sports). Each subject was given a time card and was asked to keep a record of the amount of daily wear. After 1 week, the subjects were recalled. Lip pressure was recorded with the expansion-simulating stent.

Statistical analysis

Lip pressure was recorded. A repeated measures ANOVA was used to determine significant differences among the three pressure recordings (pretreatment nonexpansion, pretreatment expansion, and posttreatment expansion). Post-hoc comparisons were based on Fisher's Pairwise Procedure. $P < 0.05$ was considered significant for both tests. To determine the increase in pressure associated with the simulated expansion, the pressure values from the pretreatment stents (both with and without simulated expansion) were compared. To determine the degree of pressure change or adaptation over the week, the pressure values from the expanded stents, before and after the week, were compared. Finally, to determine the extent of adaptation relative to the initial pressure levels, pressure value from the pretreatment stent without expansion was compared with the posttreatment stent with expansion.

Results

The average lip pressures with the nonexpanded stents were 7.4 x 10^2N/m^2 for the midline and 4.5 x 10^2N/m^2 for the canine. The average pressures recorded when the expanded stents were initially placed were 13.5 and 9.2 x 10^2N/m^2 for the midline and canine respectively. After 1 week of expansion-simulating stent wear, the average pressures recorded with the expanded stent were 9.4 and 9.5 x 10^2N/m^2 for the midline and canine, respectively (Table 2 and Figure 2). The ANOVA revealed significant variation for both the midline and canine areas when the three pressure tests were compared ($P = 0.0066$ for the midline and $P = 0.0087$ for the canine). The post-hoc comparisons revealed a significant increase in pressure associated with the simulated expansion for both the midline and canine areas (pretreatment nonexpanded stent compared with pretreatment expanded stent, $P = 0.0019$ for the midline and 0.0064 for the canine, Table 3). The effect of wearing an expansion-simulating stent for 1 week (expanded pretreatment stent compared with expanded posttreatment stent) was a significant reduction in pressure for the midline ($P = 0.0430$), but no significant change for the canine ($P = 0.9218$, Table 3). The extent of adaptation when compared with the pretreatment pressures was sig-

Table 2
Lip pressure values: at initial test without simulated arch expansion; at initial with simulated arch expansion; and at one-week with simulated arch expansion. Values and standard deviations (±) given in 10^2N/m^2.

	Initial nonextended	Initial extended	1 week extended
Midline pressures	7.4 ± 6.8	13.5 ± 6.8	9.4 ± 6.1
Canine pressures	4.5 ± 4.3	9.2 ± 8.1	9.5 ± 6.5

Table 3
Results of the Fisher's Pairwise Procedure (p values) evaluating differences between the initial pressure without expansion, the initial pressure with simulated expansion, and the pressure at one week with expansion. Significance assigned at P<0.05.

	Midline	Canine
Difference between initial stent without simulated expansion and initial stent with expansion	0.0019	0.0064
Difference between initial with expansion and 1-week with expansion	0.0430	0.9218
Difference between initial without expansion and 1-week with expansion	0.2531	0.0058

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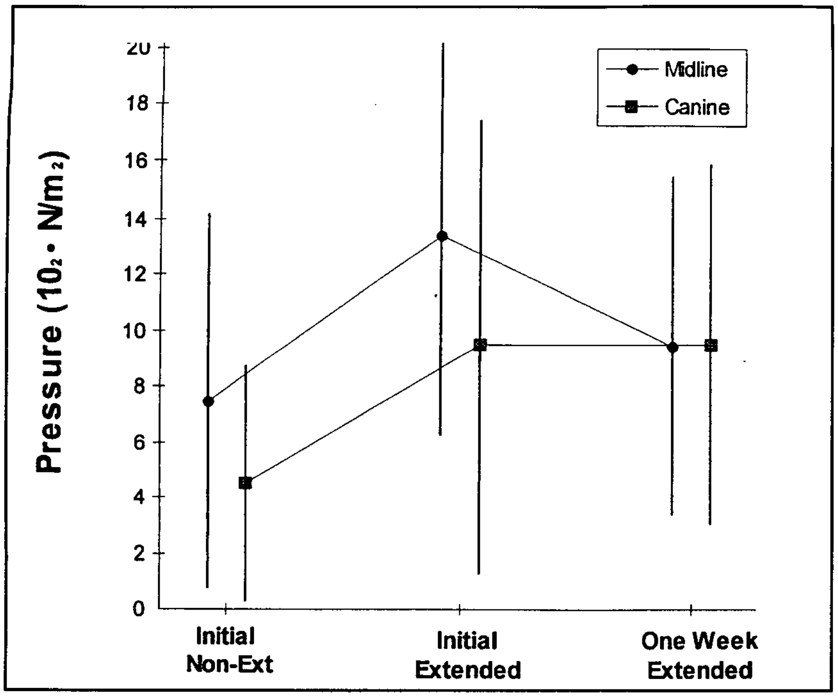

Figure 2
Graph of resting lip pressures illustrating changes occuring with simulated expansion and with time. Vertical bars represent standard deviation.

nificant for the midline (the pressure decreased to the point that the posttreatment expanded stent pressure was not significantly different from the pretreatment nonexpanded stent pressure, P = 0.2531), but not for the canine (the posttreatment expanded stent pressure was still significantly different from the pretreatment nonexpanded stent, P = 0.0058, Table 3).

Discussion

Lip pressure changes with 1 week of simulated arch expansion

Midline lip pressure with simulated expansion decreased significantly following 1 week of simulated mandibular dental expansion, to the point that it was no longer significantly different from the pretreatment nonexpanded lip pressure (Figure 2). However, lip pressure in the canine area did not change significantly with 1 week of simulated expansion. These findings may indicate an adaptive response of the lower lip that varies according to location. A difference in response between the mandibular midline and a mandibular canine was also reported by Soo and Moore.[19] This difference in adaptation may be due to the difference in the anatomic structure of the soft tissues in the two locations. The involvement of different muscle groups in the canine area may limit the ability of the tissues in this area to adapt to the new position of the teeth. This may have an important clinical implication. If the dental arch has to be expanded, it may be more stable to expand in the area of the incisors than the canines.

Although a possible adaptive response was observed in the midline, the results of this study may explain the instability seen after mandibular dental arch expansion. When the lip was initially displaced, a significant increase in pressure was observed. After 1 week, the pressure in the canine area was still significantly higher than it had been before expansion, and the midline pressure was also higher than recorded initially, though not significantly so. The residual increase in labial pressure may still affect the position of the teeth once retaining devices are discontinued.

The adaptation seen in this study is similar to that found in some of the subjects studied by McNulty et al.[20] In that study, after wearing for 1 week a denture in which the teeth were 3 mm protrusive relative to their former position, two of five subjects exhibited patterns of lip pressure that could be characterized as adaptation. The results were not analyzed statistically as the study size was too small. The current study was large enough to accommodate statistical analysis and it supports the conclusion by McNulty et al., that some subjects "reacted to incisor protrusion by…muscle accommodation."

The results of the current study are more difficult to compare with results of the study by Soo and Moore because of the differences in study design.[19] Subjects in Soo and Moore's study achieved mandibular arch expansion (average of 1.5 mm of labial movement of the mandibular incisal edge as evaluated cephalometrically) after using a passive expansion device (lip bumper). In the current study the teeth were not allowed to move, thus one variable (tooth movement) was eliminated and the effect of simulated expansion on lip pressure was isolated. Another difference between these studies is the time interval. The current study evaluated changes at 1 week (as McNulty did), and Soo and Moore looked at changes at 1 month and 8 months. Even with these differences in design, it is interesting to compare the results of these two studies. Soo and Moore found resting pressures in the midline to increase at 1 month, then to decrease to below the initial level by 8 months, even though the teeth had moved forward. Resting pressures in the canine area decreased at 1 month, then

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decreased even further by 8 months. Actual changes in canine positions were not reported. The data from these two studies are not directly comparable, but the changes shown by Soo and Moore may indicate a different pattern of adaptation (canine area pressures decreased significantly, whereas in the current study canine pressures did not decrease significantly) and extent of adaptation (pressures in both areas decreased to levels below the initial pressure levels, whereas in the current study the pressures in both areas remained above the levels initially registered). A number of variables, including the length of time involved in the studies, could be responsible for these differences, but it is not yet possible to rule out a difference in the adaptation induced. If there is a difference in the quality and/or the quantity of adaptation induced, there may also be differences in the stability of the two treatments (arch expansion with a passive strategy such as a lip bumper vs. expanding the arches without holding the soft tissues away from the teeth).

Lip pressure variability

Most lip pressure studies have demonstrated high interindividual variability.[19-20,22-24] In this study, an attempt was made to control this variability by recruiting subjects within a limited age range (20-30 years of age). However, high interindividual variability was still observed. This may be due to inherent differences between individuals. Future studies could explore these differences and their possible influence on the stability of orthodontic treatment.

Recording time of wear

Unfortunately, only a small percentage of subjects returned time cards (5 of 22 = 23%). Due to the potential errors associated with calculating time of wear from memory, correlation of wear time with changes in lip pressure were not considered meaningful. The difficulties encountered in obtaining accurate records of the amount of wear are not unfamiliar to clinical orthodontists, whether they are attempting to encourage headgear wear, functional appliance wear, or elastic wear. Preprinted cards were used in an attempt to enhance accuracy of the recording, yet the response was poor. It may be necessary in the future to implement a system of daily reporting or to devise other methods of obtaining accurate records of cooperation.

Additional studies needed

This study measured the changes in lip pressure after 1 week of simulated expansion in a specific age group. To understand the effects of dental movement on the pressure equilibrium, the effect on pressures from the tongue must also be investigated. While 1 week information is valuable, orthodontic stability is a long-term proposition and intraoral pressure changes must be studied on a much more extended basis as well. In addition, it would be informative to investigate the response of the intraoral soft tissues to dental movements in other age groups. Finally, studies are needed to examine other possible contributors to postorthodontic treatment instability.

Conclusions

The following may be concluded from the analysis of data obtained from 22 human subjects before and after wearing a stent for 1 week to simulate mandibular dental arch expansion:

1. Lip pressure in the midline decreased significantly after 1 week of simulated expansion. This finding suggests an adaptive response of the lower lip to simulated dental arch expansion.
2. Lip pressure with simulated dental arch expansion did not return to the preexperimental level (no expansion simulated). The residual increase in labial pressure may still affect the position of the teeth and may contribute to instability.

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