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DOI: 10.2478/aoj-2000-0004

Original Article

Electropalatographic and cephalometric assessment of myofunctional therapy in open-bite subjects

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Myofunctional therapy (MFT) is often prescribed to correct tongue-thrust swallowing, with the expectation that anterior open bite (AOB) will reduce spontaneously if a more posterior tongue posture is learned. However, MFT has not been subjected to systematic evaluation. Electropalatography (EPG), which is used in speech pathology to measure dynamic tongue function for diagnostic, therapeutic and research purposes, is a suitable technique for the evaluation of MFT.

This prospective clinical study assessed the effect of tongue re-education therapy on tongue function and dento-facial form in AOB patients. Electropalatography recordings of speech and swallowing, and lateral head cephalometric radiographs were obtained from eight 10-year-old boys with tongue-thrust swallowing behaviour and AOB before and after a course of tongue re-education therapy.

Although differences in cephalometric measurements before and after therapy were small, there was some evidence of a trend for upper and lower incisor eruption, with concomitant reduction of the AOB. Analysis of the EPG speech data was inconclusive, but the swallowing data showed trends for more consistent and more anterior patterns of EPG contact after therapy. Comparison of pre- and post-therapy EPG data with data from a parallel study using a group of age-matched controls indicated that some "normalisation" of swallowing behaviour had occurred. The results of this research imply that the therapy was partially successful in improving tongue function during swallowing and in reducing AOB.

Further research on a larger sample over a longer observation period is required for more accurate assessment of soft and hard tissue changes.

Aust Orthod J 2000; 16: 23–33

Key words: Anterior open bite, electropalatography, myofunctional therapy, swallowing

Received for publication: November 1998
Accepted: October 1999

Introduction

Anterior open bite (AOB) and fronted tongue posture are frequently associated, but despite much work, the relationship between the two is not completely understood.[1] Tongue-thrust swallowing is a normal feature of suckling and children also exhibit this swallowing pattern during the transition between the deciduous and permanent dentitions.[2] Although there is evidence that anterior tongue posture may prevent the eruption of the anterior teeth,[3] other evidence suggests that tongue-thrust swallowing is an adaptation to open bite that facilitates an anterior oral seal rather than being its cause.[4,5]

The effect of different orthodontic and non-orthodontic treatment modalities on AOB, fronted tongue posture and swallowing have not been clearly established, and further investigation into the effects of treatment on these conditions would be beneficial. The intra-oral measurement of tongue position during function is difficult, but a reproducible method of measurement of tongue activity is necessary for such assessment. Currently available measurement techniques are either limited to being able to record static rather than dynamic information, such as the early "wipe-off" palatograms, or interfere with function, as with electropalatography (EPG). In this technique, an acrylic palatal baseplate fitted with a number of electrodes (Figure 1) is used to record the location and timing of tongue contacts with the hard palate (or, more accurately, with the acrylic baseplate) during continuous function.[6] Each electrode is electrically connected to a personal computer containing an EPG3 interface card, which allows details of linguo-palatal contact for all electrodes to be stored to disk in real time. Electropalatography is a convenient method of measuring dynamic tongue function, which is

Table I. Mean cephalometric values before and after therapy (standard deviations in parentheses).

Variable	Before therapy	After therapy	Mean difference	t	Significance
SN-MP (°)	35.5 (3.8)	36.1 (4.1)	0.6	0.32	ns
SN-PP (°)	5.6 (3.3)	6.0 (3.5)	0.4	0.21	ns
SNA (°)	82.1 (4.6)	81.9 (4.4)	-0.3	0.13	ns
SNB (°)	77.3 (3.4)	77.6 (4.3)	0.3	0.14	ns
ANB (°)	4.9 (2.5)	4.3 (2.2)	-0.6	0.48	ns
N-PP (mm)	49.9 (1.8)	50.9 (1.5)	1.1	1.22	ns
PP-Me (mm)	64.3 (4.3)	64.8 (4.5)	0.5	0.23	ns
AFH (mm)	114.1 (4.4)	115.7 (5.1)	1.6	0.65	ns
Is-PP (mm)	28.1 (3.8)	28.4 (3.3)	0.4	0.20	ns
Ii-MP (mm)	37.0 (3.9)	38.4 (3.8)	1.4	0.70	ns
AOB (mm)	4.0 (1.5)	3.1 (2.3)	-0.9	0.92	ns
U1-SN (°)	109.8 (6.2)	109.1 (7.7)	-0.7	0.20	ns
U1-PP (°)	115.4 (5.8)	115.1 (7.2)	-0.4	0.11	ns
IMPA (°)	94.9 (7.9)	96.6 (7.1)	1.6	0.43	ns
IIA (°)	120.5 (8.7)	118.4 (6.3)	-2.1	0.56	ns
ILG (mm)	1.7 (3.1)	4.1 (3.3)	2.4	1.36	ns
NLA (°)	108.8 (6.5)	106.9 (10.4)	-1.9	0.44	ns

ns: $p > 0.05$ (not significant) n = 14

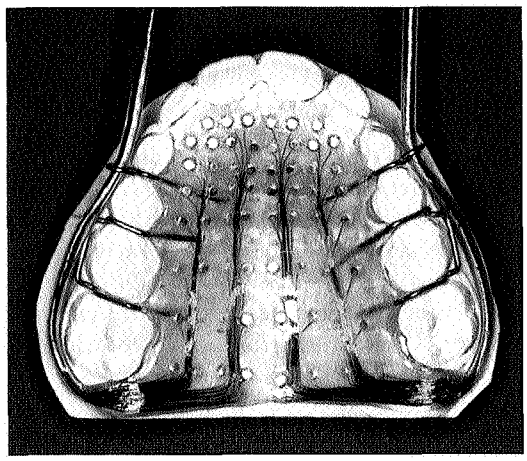


Figure 1. An electropalatography plate.

used as a diagnostic, therapeutic and research tool by speech pathologists[7,8,9,10] although it has not been used widely in orthodontic research.

The present study used EPG and cephalometrics to assess the effectiveness of myofunctional therapy (MFT) in producing soft and hard tissue change in a group of AOB patients, and to produce a core of experimental data for further research.

Materials and methods

The sample group consisted of eight boys of mean age 9.93 ± 1.02 years (range 9.08 – 11.75 years) who had either anterior open bite or incomplete overbite of 3 mm or more, and were assessed by the principal author and a speech pathologist to exhibit a tongue-thrust swallowing pattern with interposition of the tongue between the teeth.

Pre- and post-therapy lateral head cephalometric radiographs were traced and measured by the same operator, using 400 mm 2 x magnification loupes. The angular and linear measurements listed in Table I were selected to reveal any dento-facial change occurring during the observation period. A graphical representation of the landmarks, and angular and linear measurements can be found in Figure 2. To assess reproducibility of the cephalometric measurement technique, five pre-therapy films were retraced using the same technique and equipment. Comparison of values showed that all linear measurements were accurate to within 1mm, and that, except for the naso-labial angle, all angular measurements were accurate to within 2 degrees. Differences between mean values of the cephalometric variables before and after therapy were compared using paired t-tests, with statistical significance pre-determined at $p < 0.05$.

Table II. Closures and words used in electropalatographic analysis.

Closures*				Whole words	
Alveolar		Palato-alveolar	Velar		
/t/ack	/d/redger	/tʃ/ain	/k/astle	biscuit	razor
/t/eam	la/d/er	deck/tʃ/air	/k/lock	box	saddle
cock/t/ail	swor/d/	stre/tʃ/er	/k/itkat	castle	seesaw
s/t/retcher	threa/d/	wi/tʃ/craft	bo/k/s	catch	shack
sui/t/case	/l/eg	ca/tʃ/	co/k/tail	chain	shore
tro/t/er	c/l/ock	/ʤ/oke	de/k/chair	clock	skate
kitka/t/	s/l/ipper	dre/ʤ/er	suit/k/ase	desk	slipper
squashki/t/	cocktai/l/		witch/k/raft	door	star
star/t/	/n/ose		des/k/	dredger	sword
/d/esk	chai/n/		mathsboo/k/	feather	tack
/d/oor	bok/s/		ta/k/	flash	team
			le/g/	joke	thong
			tho/ŋ/	ladder	thread
				leg	tooth
				measure	tune
				nose	zip

*closures selected for more detailed analysis are underlined

The 62-electrode Reading System EPG system[6] was used in this investigation. An EPG plate and a "dummy" trainer plate were constructed for each child. The children were requested to wear the trainer plate full time for three days prior to each EPG recording session to allow for speech accommodation.

A phonetically balanced list of test words that included a wide range of consonant articulations in initial, medial and final positions within words in association with different vowels, was used to assess dynamic tongue activity during speech. Each child was asked to read the test words in groups of four into the microphone; a group was saved only if the words were read fluently and without mistakes. Electropalatography recordings of the subjects swallowing saliva and water were also made.

Each word from each EPG recording session was examined for closures. A closure was defined as an EPG event in which continuous contact occurred from one side of the palate to the other, thus preventing the passage of air centrally. Examples of discrete speech sounds, or phonemes, involving a closure are /ʤ/, the voiced, and /tʃ/, the voiceless initial palato-alveolar affricates in "joke" and "chain" respectively, and the medial velar stop /k/, in "suitcase". Phonemes are defined as the smallest segments of sound that can be

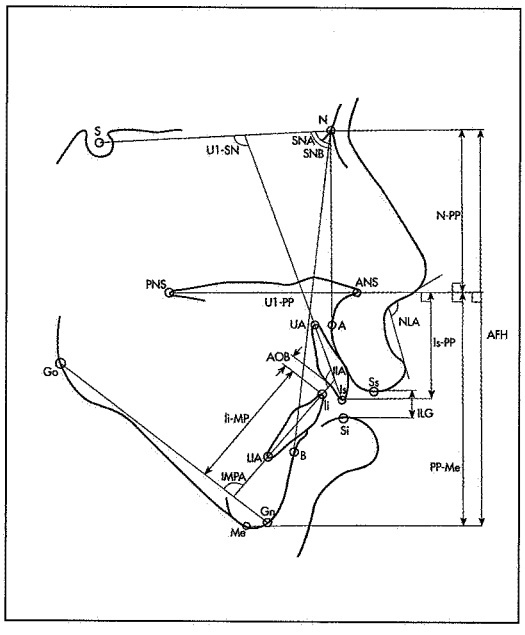


Figure 2. Cephalometric landmarks with linear and angular measurements.

distinguished by their contrast within words[11] and as in the examples on the previous page, are enclosed by forward slashes. The forty-two closures identified from the EPG data are listed in Table II. The frequency of occurrence of closures represents the number of actual closures that occurred, expressed as a percentage of the total number of possible closures for all subjects for all recordings made during a session.

A subset of closures was selected for more detailed analysis. These closures, which are underlined in Table II, represent a variety of closure types, and included the most consistently produced examples of each type. The duration, Average Notional Row Number (ANR) and closure index (Table II) were determined for these closures. The duration of each closure, measured in milliseconds, represents the length of time that the central air passage was occluded. The ANR is a nominal average representing tongue position, which is derived from the number of contacts per row over time, weighted towards the front of the palate. The derivation of the ANR, also known as the Centre of Gravity Index, is described in detail elsewhere.[10] The closure index of a closure is the product of the mean number of rows involved in a closure and the mean percentage of contacts in those rows; it is a measure of the area of linguo-palatal contact in a closure.[12] The EPG data for the saliva and water swallows were examined, and the propulsive phase of each swallow was used to calculate the ANR value for each swallow. All these parameters have been used previously for the analysis of EPG data.

The frequency of occurrence of all closures, the duration, the ANR and closure index of the eight closures selected for more detailed analysis, and the ANR of the whole words and swallows were extracted from the raw EPG data with the aid of computer software. The EPG data, consisting of three repetitions of each closure, word or swallow from the pre- and post-therapy recordings were compared to check for changes in tongue activity during the observation period. Each closure, word or swallow was recorded three times for each of the eight subjects, resulting in twenty-four recordings of each closure, word or swallow at the pre-therapy, and twenty-four at the post-therapy recording session. The frequency of occurrence, duration, ANR and closure index data were analysed with a repeated measures ANOVA, with "within child" factors of session and replication within session.* A compound symmetric error structure was assumed. Because the number of values obtained for each EPG parameter was so large, statistical significance was pre-determined at $p < 0.01$.

* Program "5V" (unbalanced repeated measures) from the BMDP Statistical Software package, Release 7, University of California, 1993.

Each child visited the speech pathologist for an initial assessment of speech and tongue function before the first EPG recording session. Tongue re-education therapy was instituted as soon as possible after the first EPG recording. A therapy protocol, consisting of four 20-minute sessions spaced fortnightly, was used. When attendance was not possible for some reason, the closest suitable appointment was given. The first stage of therapy was directed towards developing the new muscle patterns necessary as a foundation for correct swallow and correct lip and tongue postures. This was followed by instruction and practice in normal swallowing using liquid and semi-solid materials.[13] The EPG system was not used as a therapeutic aid.

Each patient was seen again within a month of completion of the course of tongue re-education therapy for a second lateral head cephalometric film and the second EPG recording, which was conducted in exactly the same way as the first.

Results

Tongue re-education therapy

The criteria for successful MFT were that the child was able to use the new and old swallows on command and that the new swallow was generalised, meaning that the new swallow was used in normal function. Table III shows details of the number of sessions required for generalisation of the learned tongue behaviour. In the case of four children (B, E, F and H), the learned swallowing pattern was generalised after only three therapy sessions; it was therefore decided that the fourth session was unnecessary. Child C was withdrawn from therapy after three sessions as his mother felt that no benefit was being gained. For child D, generalisation occurred after the fourth session. Two children (A and G) required further therapy.

Table III. Number of MFT therapy sessions required with change in AOB for experimental children.

		AOB (mm)		
Child	No. of sessions	Pre-therapy	Post-therapy	Change
A	> 4	4.5	na	na
B	3	4.0	1.5	-2.5
C	*	2.5	0	-2.5
D	4	4.5	5.5	+1.0
E	3	2.0	1.0	-1.0
F	3	6.5	6.0	-0.5
G	> 4	4.0	4.0	0
H	3	4.5	3.5	-1.0

*child withdrawn from therapy after 3 sessions
na: not available

Table IV. Mean durations of selected closures before and after therapy (standard error in parentheses).

Closure	Mean duration (milliseconds)		Mean difference	Significance
	Pre-therapy	Post-therapy		
/t/eam	112.8 (10.8)	104.2 (10.1)	8.5 (10.3)	ns
/d/oor	110.0 (7.9)	109.4 (8.0)	0.6 (10.7)	ns
/l/eg	71.8 (8.8)	94.2 (8.8)	22.4 (10.8)	ns
/n/ose	78.4 (8.9)	79.2 (9.1)	0.8 (6.6)	ns
/tʃ/ain	112.2 (12.6)	111.3 (12.3)	0.9 (13.2)	ns
/dʒ/oke	116.5 (10.1)	99.5 (10.0)	16.9 (9.3)	ns
suit/k/ase	97.6 (9.2)	105.4 (8.6)	7.9 (11.2)	ns
le/g/	87.4 (11.3)	72.4 (11.0)	15.0 (13.4)	ns

ns: $p > 0.01$ (not significant)

Cephalometric Data

Pre-therapy SN-MP values for five of the eight subjects were above 36 degrees, and values for ANB were higher than 5 degrees for four subjects. These figures suggest a high angle Class II skeletal pattern in the experimental subjects. Mean values for U1-SN and U1-PP were both increased in the subjects before therapy, indicating upper incisor proclination, and Class II division 1 malocclusion.

Mean cephalometric values for the subjects before and after therapy are summarised in Table I. By parental request, Child A had no post-therapy film taken. Cephalometric data was compared only for the seven children for whom both pre- and post-therapy films were available. Very little cephalometric change was found during the observation period. Differences for vertical and antero-posterior skeletal parameters did not even approach statistical significance. There was some evidence of a trend towards reduction of the AOB, and further eruption of the upper and lower incisor teeth. However, these differences failed to reach statistical significance. Wide variation was found in soft tissue measurements for both pre- and post-therapy conditions.

Electropalatographic data

Analysis of the frequency of occurrence data from the forty-two closures identified revealed no clear pattern of differences over the observation period. Differences for only two closures reached statistical significance: deck /tʃ/ air was made more frequently before, while /t/eam occurred more frequently after therapy. All five medial velar closures occurred more frequently after therapy, although none of these differences reached statistical significance. Variability in the frequency of occurrence of closures was high both before and after therapy.

Table IV shows the mean durations before and after therapy of the eight closures selected for further analysis. None of the differences in duration reached statistical significance between sessions. However, both the alveolar lateral, /l/, and the nasal, /n/, closures increased in length between the recordings, and both the alveolar plosives, /t/ and /d/, and the palato-alveolar affricates, /tʃ/ and /dʒ/, were shorter at the post-therapy recording. For the velar closures, no pattern was obvious. Pre- and post-therapy variability in the duration of the selected closures was similar.

Numerical ANR data and palatograms indicated that the pattern of contact after therapy for the velar closures was more posterior, but differences were small. For the remaining closures, no clear pattern emerged from the numerical ANR data or from examination of the palatograms. No differences in ANR reached statistical significance, and the values for all closures changed little between sessions. Variability in the ANR of the eight closures was virtually identical before and after therapy.

As can be seen from the palatograms and mean closure index values shown in Figure 3, values for two closures, /l/eg and le/g/, increased between the two recordings. However, for the remaining six closures, the mean closure index fell. For /tʃ/ain, this difference reached statistical significance, while for the remaining five closures, values were similar in both recordings. For all closures except /tʃ/ain, variability of the difference in values between the two sessions was near to, or greater than, the mean difference itself.

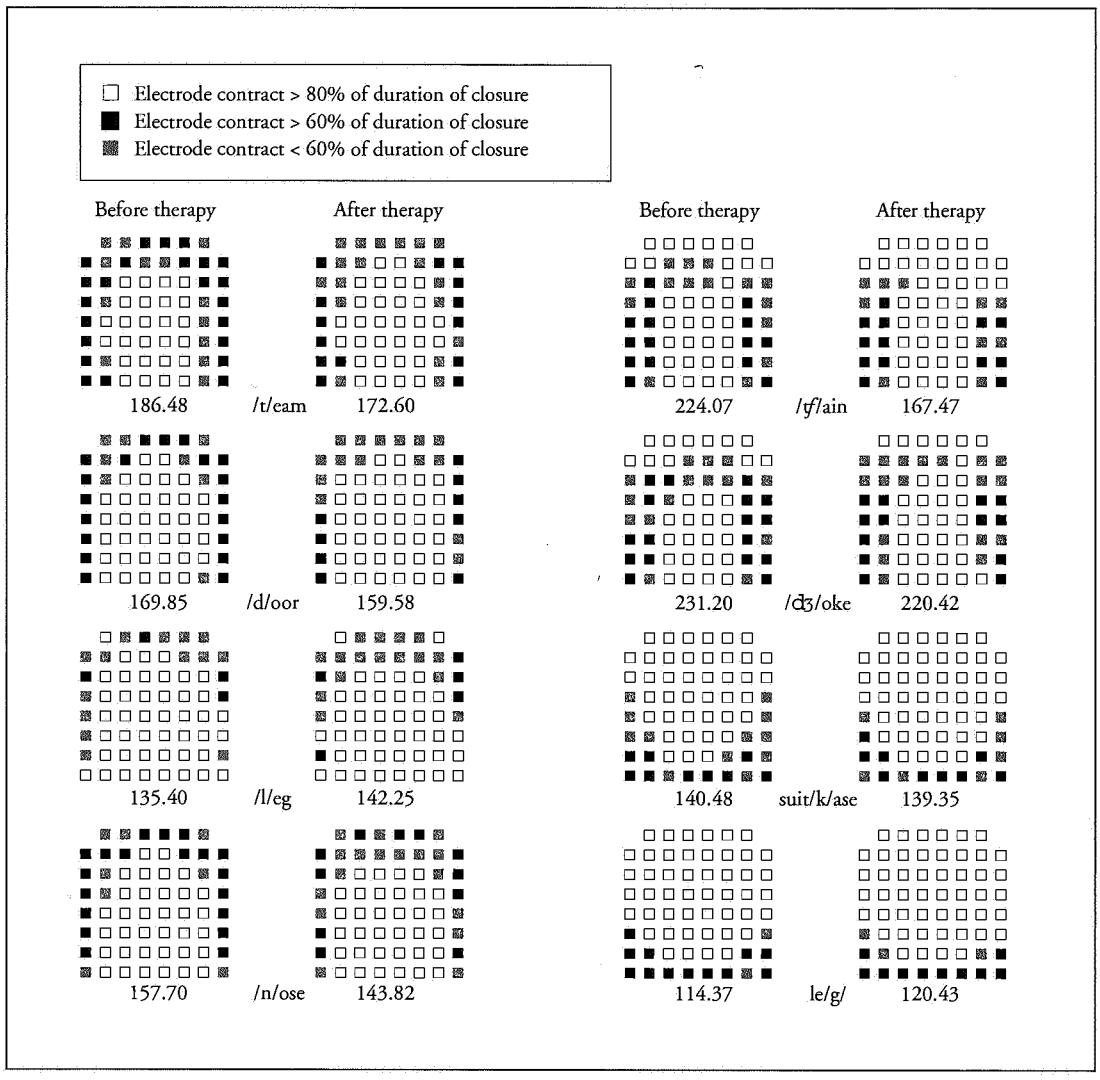


Figure 3. Palatograms and mean closure index values for selected closures before and after therapy.

No pattern of change was evident for the thirty-two whole words studied, and the numerical and the palatographic evidence was often conflicting. Pre- and post therapy variability was high.

For the swallows, differences were small and failed to reach statistical significance. However, both the palatograms and the numerical ANR data for the open-bite group before and after therapy shown in Figure 4 indicate a more anterior pattern of palatal contact after therapy. Examination of the palatograms also suggests a more consistent and definite pattern of contact for both water and saliva swallows after the course of therapy.

Discussion

This study used cephalometric and electropalatographic methods to assess the effect of swallowing re-education therapy on AOB in a group of eight 9- to 11-year-old boys. Spontaneous closure of simple AOB occurs in approximately 80 per cent of 10- to 12-year-old children.[14] The recruitment of sufficient numbers of subjects was difficult and therefore there was no control group of AOB children to assess how much closure would have occurred without therapeutic intervention.

The mean time interval between the pre- and

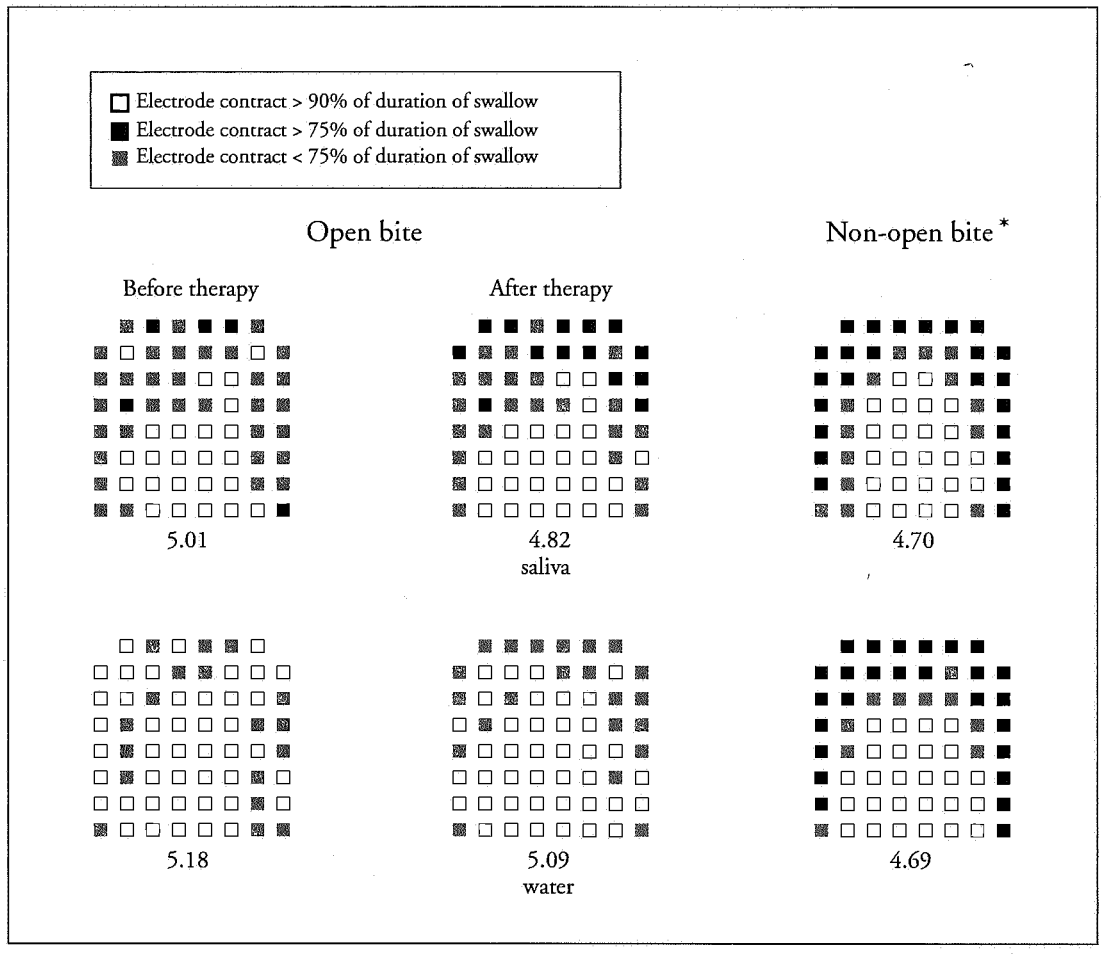


Figure 4. Palatograms and mean ANR values for saliva and water swallows for the experimental group before and after therapy, and for a non-open bite group. *From Tindall (1998)[12]

post-therapy lateral head cephalometric radiographs was 16.75 weeks, or approximately one-third of a year. Normative values for PP-Me predict that an increase of approximately 1 mm per year will occur for 10-year-old boys (McNamara, 1984).[15] The mean change during the observation period was an increase of 0.6 mm for PP-Me, which is therefore double that predicted by McNamara. However, in the radiographic error study, PP-Me was identified as one of the least reproducible cephalometric measurements. Furthermore, values for both the measured difference from the present study and the expected difference from the McNamara's normative data are small. It is probable that some facial growth did take place and that any treatment effect attributable to the MFT was superimposed upon the change due to growth. Unfortunately, no normative values for growth in AOB children are available for comparison.

For five of the children, the swallowing re-education therapy was judged to be successful; the newly learned swallowing pattern became generalised by the fourth therapy session. Although 16.75 weeks is probably insufficient time for any skeletal anatomical change attributable to the therapy to be detectable, some evidence was found for a trend for further eruption of the upper and lower incisor teeth and a reduction in AOB during the observation period. Mean differences were small and failed to reach statistical significance, but the four children who achieved generalised swallowing behaviour by the third therapy session all exhibited reduced AOB after therapy (see Table III). The large amount of EPG data generated in the study precluded individual analysis and therefore it is not known whether these beneficial effects were associated with statistically significant changes in the EPG data for these four children.

The first session of the course of swallowing re-education therapy was directed towards developing new muscle patterns, which are necessary as a foundation for a correct swallow, and for correct lip and tongue postures.[13] Good progress at this stage enabled the child to move on to learning the new swallow, even during the same session, if this was felt to be appropriate by the speech pathologist. However, there would have been little benefit in attempting to teach the new swallow had the child had difficulty in grasping these new muscle patterns. Therefore, whilst every attempt was made to standardise the MFT, it was necessary to vary the therapy according to the child's response. From Table III, it can be seen that only for child D was four sessions the correct number, and while four children (B, E, F and H) achieved a successful outcome in three sessions, two (A and G) required more than the four sessions originally planned. Child C was withdrawn as his mother could see no benefit from the therapy. Indeed, it proved impossible to motivate this child and therefore it is not surprising the outcome of his course of therapy was not ideal. Practice is a very important aspect of this type of therapy. Motivation and treatment success go hand-in-hand.[16]

Assessment of generalisation by the speech pathologist is difficult. Partly, this is because the child is likely to be reminded of the newly learned swallow simply by being in the speech therapy clinic. In addition, the child may make more effort during the therapy session because of a desire to please the speech pathologist. It is possible that the post-therapy EPG data may also have been susceptible to similar "halo" effects. In order to minimise this source of error, the children were not directed to use the newly learned swallow. However, it cannot be certain that any changes in swallowing pattern detected by EPG were reflective of a change in habitual tongue posture.

The therapeutic regime focused on correction of abnormal tongue function. Although EPG recordings were made of dry and liquid swallows, the vast majority of EPG data collected came from recordings of speech. In retrospect, as the therapy was directed at retraining errant swallowing behaviour, it may have been more informative to have investigated changes in swallowing in more detail, rather than to have placed so much emphasis on the assessment of tongue function during speech. It may have been more useful, perhaps, to have recorded more than six swallows at each recording session, and to have varied the bolus size for the liquid swallows, as in the work of Chi-Fishman and Stone.[17]

In the past, it has been noted that it has not been proven that the re-education of swallowing activity affects speech.[18] The children in the present study received swallowing re-education therapy but no speech therapy. Although no clear patterns of change in closure or whole-word data were found, some statistically significant differences were found over the observation period. Some change might be attributable to alterations in the position of the anterior teeth or to dento-facial growth but, as discussed above, little change would be expected in such a short time and, indeed, little was found. It is possible that these changes constitute evidence for such a crossover effect, with the altered swallowing pattern causing change in EPG contact patterns during speech.

In the present study, the course of therapy was directed at the alteration of tongue activity during function. However, the resting posture of the tongue is considered to be more important than functional activity in the ætiology of AOB.[5,19] Some changes in function were demonstrated after therapy, but resting tongue posture was not investigated and therefore no evidence for a change in resting tongue posture was found. Any morphological changes over the course of therapy might constitute evidence that resting posture was changed by therapy aimed at altering function. After therapy, there was a trend towards eruption of the upper and lower anterior teeth, with a concomitant reduction in AOB, but none of the changes in cephalometric variables reached statistical significance. These results imply that the therapy was partially successful in reducing AOB. It must be noted, however, that the post-therapy lateral head cephalometric radiographs were probably taken too soon after therapy for skeletal change to have been detectable, and, furthermore, no untreated AOB control group was available for comparison. A longer observation period and a larger sample group with an AOB control group are recommended for more accurate assessment of hard tissue changes.

A parallel study using the same methodology[20] compared the same eight subjects before therapy with a control group of age-matched non-open-bite children. Figure 4 shows palatograms and mean ANR values for saliva and water swallows from these non-open-bite children, and from the AOB children from the present study before and after therapy. The palatograms and the numerical ANR data both indicate a trend towards a more anterior pattern of palatal contact after therapy. As can be seen from the palatograms, it seems that

Table V. Mean ANR of saliva and water swallows before and after therapy (sandard errror in parentheses).

Swallow	Mean ANR		Mean difference	Significance
	Pre-therapy	Post-therapy		
saliva	5.01 (0.15)	4.82 (0.15)	0.20 (0.15)	ns
water	5.18 (0.12)	5.09 (0.12)	0.08 (0.11)	ns

ns $p > 0.01$ (not significant)

swallowing function in the open-bite subjects resembled the control group more closely after than before the course of therapy.

Examination of the saliva-swallow palatograms in Figure 4 shows that the pattern of central anterior linguo-palatal contact in the open-bite children includes four rows of contacts, in contrast with the pattern in the non-open-bite subjects, in which only the two front rows are involved. During a normal swallow, the tongue tip is held against the palatal mucosa immediately behind the incisal papilla, producing the pattern of contact seen in the control children. Clinical observation indicates that in the presence of AOB the tongue protrudes into the open bite so that a broader, more posterior part of the tongue contacts the anterior part of the EPG plate. This may explain the apparent contradiction that the EPG contact pattern in the AOB subjects before therapy was more posterior than in the non-open-bite control group subjects, and that, contrary to expectation, MFT appears to have produced a more anterior EPG contact pattern in the AOB subjects, partly normalising their tongue function.

Examination of the palatograms in Figure 4 suggests a more consistent and definite pattern of contact for both water and saliva swallows after the course of therapy, also more closely resembling the control group, which suggests that the MFT was partially successful in its aim of correcting the errant swallowing behaviour. However, as noted above, it is possible that some "halo" effect may have contributed to this change.

Palatograms of the swallows in Figure 4 show relatively sparse patterns of contact in the open-bite group children before therapy compared with the non-open-bite children, in whom a stronger pattern of peripheral contact and a well defined posterior palatal bolus cavity were found. It is feasible that the sporadic contact pattern seen before therapy may have been caused by reduced linguo-palatal pressure. Although previous research has demonstrated increased tongue pressure during swallowing in AOB patients,[21] other workers have shown that some tongue thrusters register little or no pressure, whereas others use very heavy linguo-palatal pressure during swallowing.[2] The post-therapy palatograms show that the pattern of contact after therapy had become more like that of the controls than before. It appears that after therapy the open-bite group subjects had improved their pattern of contact, and it may be that they also increased the force with which they held the tongue against the palate during swallowing.

Previous work (Hamlet, 1989)[22] has established that saliva and water swallows are different in nature, with greater tongue-to-palate contact occurring in the saliva swallow. The results of the present study, and particularly the palatographic representations of the saliva and water swallows shown in Figure 4, are in accordance with Hamlet's findings, but her subjects were not selected for AOB; it would appear that the present study is the first to have examined swallowing function in AOB children.

There is some evidence that sensory feedback of bolus size modifies pharyngeal and oral function during swallowing,[22] although the effect on linguo-palatal contact patterns may be small.[17] The mean bolus size used in thin liquid swallowing has been found to be 21mL, and it has been suggested that the bolus size for investigation of swallowing in men should be 25 mL, and 20 mL in women.[23] Unfortunately, no recommendation was made for the ideal bolus size for use with pre-adolescent boys. In the present study, no attempt was made to standardise the size of the liquid bolus swallowed, and this might have been expected to increase the variability found in the water swallows. Table V summarises the mean ANR values for both water and saliva swallows, before and after therapy. As can be seen from the table, values for the standard error were low for all groups for the saliva swallows, and even lower

for the water swallows. It is also notable that the variability was consistent between sessions for each swallow type. Although Hamlet found that bolus size has some effect on the variability of liquid swallows,[22] the low variability of the results of the present study indicate that standardisation of the bolus size is unnecessary. This may be either because the children drew reproducible volumes of water into their mouths unaided, which seems unlikely, or because the variability of ANR values is not greatly influenced by bolus size. Nevertheless, bolus size standardisation would have eliminated this potential source of error from the data.

Principal findings

Electropalatography proved to be suitable for the investigation of tongue function in AOB patients.

Although some evidence was found for a trend towards further eruption of the upper and lower incisors, and reduced AOB, the observation period in the present study was probably too short to show significant cephalometric change.

For the EPG data, no clear patterns were found in pre- and post-therapy differences for the frequency of occurrence, duration, ANR, or closure index of closures, nor for the ANR of whole words.

Analysis of the EPG data for swallows indicated a trend towards a more anterior pattern of palatal contact, and a more consistent and definite pattern of contact after therapy for the water and saliva swallows, but differences failed to reach statistical significance.

Comparison of the pre- and post-therapy palatograms with those from an age-matched control group of non-open-bite children indicated that the swallowing re-education therapy was partially successful in "normalising" tongue function during swallowing.

Potential remains for further analysis of the data already collected, including individual rather than group analysis of data, and assessment of the sounds not examined in the present study. Longer term follow-up of the soft and hard tissue effects of MFT using a larger sample group is recommended.

Acknowledgements

The authors wish to thank John Henderson and Chris Wallace for the use of their EPG data analysis software, Paul McCormack and Alison Russell from the Flinders University Department of Speech Pathology, who performed the tongue re-education therapy, and Phil Leppard of the University of Adelaide Department of Statistics for his assistance with the data analysis. The authors are also grateful to the Australian Society of Orthodontists' Foundation for Research and Education for its financial support.

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