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Quantitative evaluation of lip symmetry in functional asymmetry

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SUMMARY The objectives of this study were to quantitate lip symmetry/asymmetry from clinical photographs; to demonstrate that asymmetry due to functional side shifts (functional asymmetry) leading to unilateral crossbites including the canines, results from measurable thinning of the upper lip and thickening of the lower lip on the side of the crossbite when viewed in the intercuspal contact position; and to show that orthodontic treatment aimed at eliminating the functional shift and crossbite would achieve lip symmetry, both visually and quantitatively.

The study consisted of 26 patients, who were divided into two groups: a study group of 13 patients (eight females, five males, aged 8–17 years) with a functional asymmetry, and a control group of 13 age- and gender-matched subjects with other forms of malocclusion without functional asymmetry. All patients in the study group exhibited unilateral crossbites including the canines in intercuspal contact position. Digitized images of frontal facial photographs were analysed for upper and lower lip symmetry pre- and post-orthodontic treatment. The upper and lower lips were subdivided into four quadrants and the surface area and length of each quadrant were measured and expressed as a percentage of the total surface area/length of the relevant lip. The degree of asymmetry was obtained by calculating the difference in percentage area or length between the two quadrants of each lip.

In the study group, the lower lip quadrant on the shift side was enlarged while the contralateral side was reduced (mean area ratio 59.9 to 40.1 per cent, mean length ratio 53.0 to 47.0 per cent). The upper lip demonstrated differences that were smaller and inverse. The controls showed a small difference between the right and left sides (less than 1 per cent). After treatment, both groups displayed visual and quantitative lower and upper lip symmetry, i.e. an area or length of approximately 50 per cent of each quadrant. In absolute values, the control patients had up to 3 per cent asymmetry in area regardless of treatment. The patients in the study group exhibited mean absolute asymmetry of 9.2 per cent in the upper lip and 19.8 per cent in the lower lip. Asymmetry values in the study group were reduced to approximately 3 per cent post-treatment. The absolute values of asymmetry in length of all patients were up to 2 per cent in the control group regardless of treatment. The subjects in the study group exhibited mean absolute asymmetry of 6.3 per cent in the upper lip and 8.6 per cent in the lower lip. Asymmetry values in the study group were reduced post-treatment to approximately 2 per cent.

Although asymmetry in the study group could be quantitated using both parameters (lip surface area and lip length), the surface area parameter proved to be a more sensitive tool for measuring lip asymmetry.

Introduction

Dentofacial asymmetry is a facial deformity which is usually associated with a skeletal component. Although the development of an asymmetry is not fully understood, several aetiological factors are recognized: (1) genetic or congenital malformations, such as hemifacial microsomia, cleft lip and palate, hemimandibular hypertrophy or elongation (Severt and Proffit, 1997); (2) environmental, such as mouth breathing (Pirttiniemi, 1994); and (3) functional, due to occlusal interferences in the path of mandibular closure, resulting in a side shift (Bishara *et al.*, 1994; Mossey, 1999). An asymmetry may be present in the vertical, sagittal, or transverse plane, or a combination in all three planes of space. Asymmetry in the transverse plane is the most perceptive to the eyes of the patient and the observer (Proffit *et al.*, 1990). Transverse asymmetry associated with a functional side shift is quite common in the primary, mixed and transitional dentitions (Pirttiniemi, 1994). Changes in the arch width dimension can result in dental malalignment due to sucking habits and impaired nasal breathing (Linder-Aronson, 1970). Thus, the created occlusal interferences could guide the mandible into an acquired asymmetric maximal closure, which causes a transverse component of asymmetry. In these cases, interarch tooth relationships often exhibit unilateral crossbites extending to the canines or to the anterior teeth. The contralateral side may exhibit a crossbite or a normal buccolingual relationship. The antero-posterior jaw relationships are also affected, exhibiting more of a Class II relationship on the side of the shift and crossbite (Bishara *et al.*, 1994). In these situations, it is important to determine the retruded contact position (RCP) and the degree and direction of the functional slide to the intercuspal contact position (ICP). The prevalence of this functional asymmetry varies between 8 and 16 per cent (Thilander *et al.*, 1984).

The long-standing presence of functional asymmetry in a dynamic growing and continuously changing stomatognathic system may produce clinical situations, such as canting of the occlusal planes, vertical growth of unsupported dentoalveolar units, temporomandibular joint adaptational changes and increasing skeletal asymmetry (Mongini, 1984; O'Byrn *et al.*, 1995). Muscle activity and function adapt to the malocclusion making the RCP difficult to determine (Ingervall and Thilander, 1975; Brin *et al.*, 1996). In these cases it is necessary to 'de-programme' the muscle memory with a bite splint prior to RCP registration (Mongini, 1982; Mongini and Schmid, 1987). It is obvious that reversing these dynamic processes becomes extremely difficult and demands more complex treatment (Brin *et al.*, 1996; Padwa *et al.*, 1997; Pirttiniemi, 1998).

Facial soft tissue architecture is the most important factor that highlights the presence of an asymmetry with or without a skeletal component. With regard to transverse asymmetries, most of the literature focuses on the hard tissue architecture of the lower jaw (Cook, 1980; Grayson *et al.*, 1983; Forsberg *et al.*, 1984; Rose *et al.*, 1994). For the soft tissues, the focus is on the outline of the lower third of the face, mainly the location of the midpoint of the chin (Bishara *et al.*, 1994; Edler *et al.*, 2001). To the best of our knowledge, there has been no clinical study published on lip asymmetry.

Clinically, in the present study, it was observed that asymmetry due to a functional side shift, associated with a unilateral buccal crossbite, including the canine and occasionally an incisor, could supply differential support to the left and right sides of the lips. This would result in a mild upper lip thinning and substantial lower lip thickening on the crossbite side when compared with the contralateral side. The lower face in general, and the lip architecture in particular, appear quite symmetrical in the RCP, or at rest with the lips apart. However, the mandibular shift and lip asymmetry are noticeable with each mandibular closure, swallowing and occasionally with speech. For a crossbite to cause lip asymmetry, the canine and possibly additional anterior teeth should be involved. Qualitative observations regarding lip symmetry have been briefly reported (Mongini and Schmid, 1987).

To support the present observations scientifically (i.e. quantitatively) a prospective investigation was conducted in which patients with functional side shifts and unilateral crossbites involving the canine were consecutively recruited upon arrival for orthodontic treatment over a 1 year period. Because the patients ranged in age from 8 to 17 years, they exhibited crossbite of the primary and permanent canines.

The objectives of this study were to quantitate lip symmetry/asymmetry from clinical photographs; to demonstrate that asymmetry due to functional side shifts (functional asymmetry) leading to unilateral crossbites including the canines, results in measurable thinning of the upper lip and thickening of the lower lip on the side of the crossbite when viewed in the ICP; and to show that orthodontic treatment aimed at eliminating the functional shift and crossbite would achieve lip symmetry, both visually and quantitatively.

Subjects and methods

Patient selection

Twenty-six patients were recruited from an orthodontic practice prior to treatment. The study group consisted of 13 patients (eight females and five males), aged 8–17 years (mean 10.3 years), with the following inclusion criteria: a functional side shift leading to transverse asymmetry of the lower face in the ICP; a unilateral crossbite extending to the primary or permanent canine and occasionally additional anterior tooth/teeth; and competent lips.

The control group comprised 13 age- and gender-matched patients with other forms of malocclusion but without a functional shift and crossbite. A clinical and panoramic radiograph examination to assess dental, facial, and major skeletal asymmetry was carried out for both groups. The assessment of skeletal asymmetry was performed clinically while the mandible was in the RCP or at rest. When asymmetry was visually detected in these positions the patients were excluded from the study group. Of the 13 patients, two were post-growth. All patients looked symmetrical in the RCP prior to the side shift leading to the ICP. A frontal face photograph in the ICP was taken prior to orthodontic treatment.

Orthodontic treatment

In the study group the crossbite was corrected as follows: a symmetrical maxillary arch expansion device was first used to treat patients in the mixed dentition. When there was resolution of the crossbite, treatment continued with partial bonding of the maxillary anterior teeth for aesthetic or functional demands. Before debonding, care was taken to ensure occlusal stability and selective grinding was performed when necessary on primary teeth only. Patients in the permanent dentition received rapid palatal expansion treatment for maxillary arch expansion followed by full bonding to achieve optimal anterior alignment with normal overjet and overbite, buccolingual and mesiodistal relationships. Stable occlusal contacts were established at the end of treatment. The control group had various treatments, all carried out with fixed appliances to achieve optimal interarch relationships.

A frontal face photograph of each patient was taken in the ICP when the orthodontic treatment was completed.

Photographic procedure

One person took all the facial photographs in the same room, using the same camera (Nikon FE2 with a Kiron 105 mm lens and a Holgon RF-50 macro-lite flash) and colour print 100 ASA film. The patient was seated and requested to look straight at the camera and to keep their head perpendicular to the floor. Special care was taken to ensure frontal head posture with no side rotation around the vertical axis of the head. The distance from the patient to the camera was focused at 1.2 magnification. Glasses were removed and the patient was asked to close the back teeth and lightly close the lips.

Data collection

All frontal photographs were scanned using a Hewlett-Packard S20 scanner. The lower half of the face was enlarged and saved as a digital image. Four photographs, three from the study group and one from the control group, are shown pre- and post-orthodontic treatment (Figures 1a–d, 2a–d). A vertical line from the midpoint of the base of the nose (the mid-distance between the inner outline of the nostrils) through the midpoint of the philtrum towards the chin was superimposed on the images (Figure 2f). The midpoint of the chin did not fall on this line in the study group.

Figure 1 Frontal view of three patients from the study group with various degrees of asymmetry. (a) Pre-treatment asymmetry 20.6 per cent, (b) post-treatment 0.6 per cent, (c) pre-treatment asymmetry 7.4 per cent, (d) post-treatment 2.6 per cent; (e) pre-treatment asymmetry 17.8 per cent, (f) post-treatment 1.4 per cent.

The lip outline and the transverse line at the merging of the two lips were carefully drawn to create (together with the vertical line) four quadrants (Figure 2e,f), two making up the upper lip and two the lower lip. The surface area and length (along the lip border) of each quadrant was measured with the Bioquant Nova Software (R&M Biometrics, Nashville, TN, USA). Data from each of the upper or lower lip quadrants were expressed as a percentage of the total surface area/length of the relevant lip. Additionally, lip asymmetry was calculated as the absolute value of the difference in percentage of area or length between the two quadrants of each lip, according to the formula: asymmetry = (right segment value − left segment value) × 100/(right segment value + left segment value). This calculation uses the sum of right + left values (which varied between patients). Thus, perfect symmetry would result in a zero value. The absolute value was used as patients in the control group had slight lip asymmetry to either the right or left side.

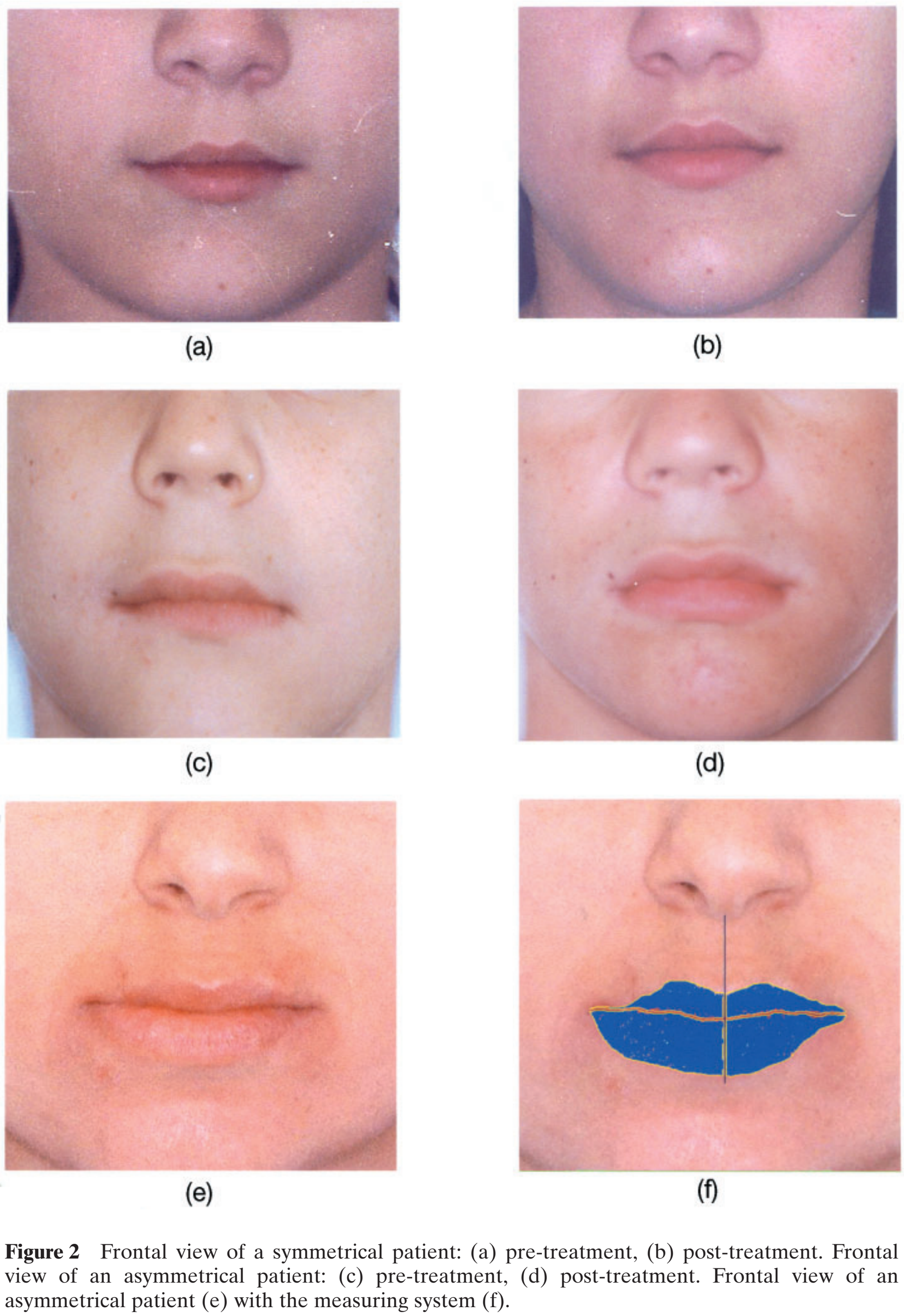

Figure 2 Frontal view of a symmetrical patient: (a) pre-treatment, (b) post-treatment. Frontal view of an asymmetrical patient: (c) pre-treatment, (d) post-treatment. Frontal view of an asymmetrical patient (e) with the measuring system (f).

Reproducibility

Area and length were measured five times in eight patients to determine the reproducibility of the measurements and the coefficient of variation (CV) for each parameter was calculated. The mean CVs of area and length measurements were 2.35 and 1.95 per cent, respectively, indicating that these measurements were highly reproducible.

Statistical analysis

Differences between area and length values of the quadrants of each lip (one side versus the other, and pre- versus post-treatment) were evaluated with a paired *t*-test.

Results

All patients displayed visual lip asymmetry in the study group compared with the controls where no lip asymmetry was observed. The mean percentage surface area of each of the two quadrants of the lower lip pre- and post-treatment in both groups is shown in Figure 3. In patients with perfect symmetry, each half of the lip occupied 50 per cent of the total lip area.

The mean values of the lower lip surface area quadrants ranged between 49.6 and 50.4 per cent regardless of orthodontic treatment in the controls. In the study group, the difference in percentage area between the lip quadrants pre-treatment was remarkable. A mean ratio of 59.9 to 40.1 per cent was measured between the lower lip quadrants, indicating that the lower lip quadrant on the side of the shift was greatly enlarged. These pre-treatment differences were highly significant ($P < 0.001$). After orthodontic treatment there was a mean residual difference of 1.2 per cent. Thus, the study group showed a reduction in lip thickness on the side where the shift and crossbite presented pre-treatment (from 59.9 to 50.6 per cent). At the same time, all patients in the study group showed an increase in lip thickness on the contralateral side from 40.1 to 49.4 per cent. These changes in lip quadrant area, associated with the orthodontic treatment, were highly significant ($P < 0.001$).

Figure 4 demonstrates the percentage of the surface area of the lower lip quadrants pre- and post-orthodontic treatment for each individual patient in both groups. Note that prior to treatment, each patient in the study group showed remarkable differences between the two lower quadrants. On completion of orthodontic treatment the lip surface area in the study group approached 50 per cent in each patient. In the control group, changes were subtle pre- and post-treatment and varied slightly around 50 per cent. These data indicate that lower lip symmetry was achieved in all treated patients.

The mean percentage surface area of each of the two halves of the upper lip pre- and post-treatment in both groups is shown in Figure 5. In the controls, the mean values of the upper lip surface area quadrants ranged between 49.4 and 50.6 per cent regardless of the orthodontic treatment. A mean ratio of 45.9 to 54.1 per cent of the study group pre-treatment was measured between the upper lip quadrants, indicating that the upper lip quadrant on the side of the shift was greatly reduced in area. The post-treatment ratio was 50.1 to 49.9 per cent. Figure 6 shows the absolute values of asymmetry in lip area of all patients. In the control group, patients had up to 3 per cent asymmetry in area regardless of treatment. In contrast, those in the study group exhibited mean asymmetry of 9.2 per cent in the upper lip and 19.8 per cent in the lower lip pre-treatment. This finding corroborates the clinical

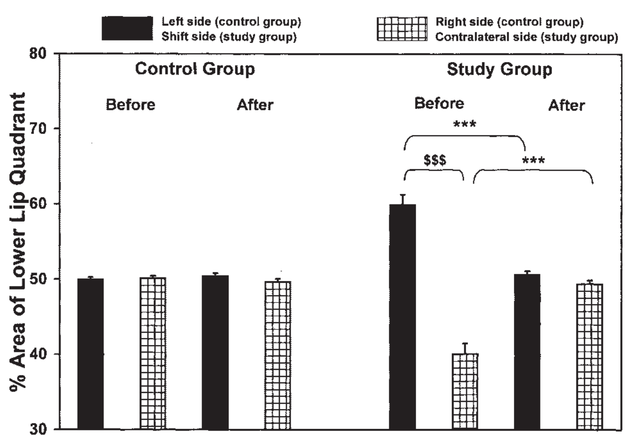

Figure 3 Mean values of the percentage area of the lower lip quadrants. Note the asymmetry in the lower lip in the study group before treatment. $$$P < 0.001 (between pre-treatment values); ***P < 0.001 (before versus after treatment).

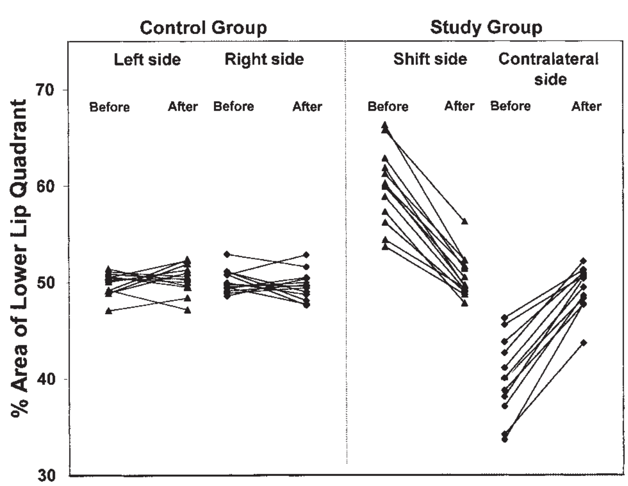

Figure 4 Individual patient data from Figure 3. The surface area of each lower quadrant pre- and post-treatment is connected with a line.

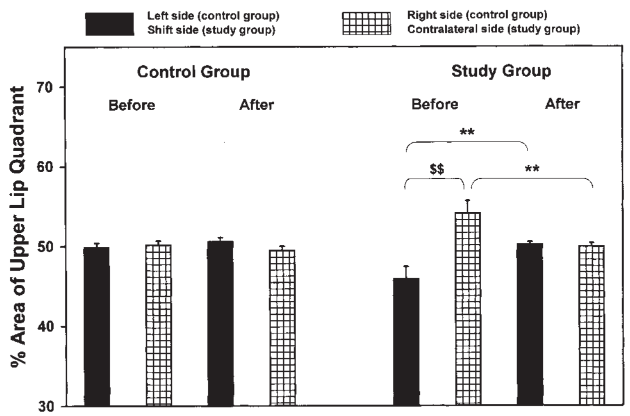

Figure 5 Mean values of the percentage area of the upper lip quadrants. Note the inverse asymmetry in the upper lip in the study group pre-treatment. $^{\$\$}P < 0.01$ (between pre-treatment values); $^{**}P < 0.01$ (before versus after treatment).

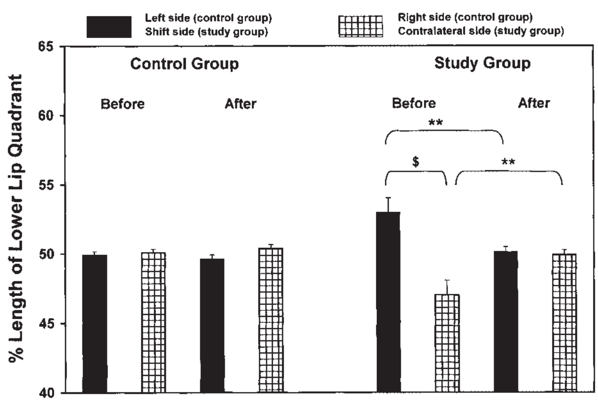

Figure 7 Mean values of the percentage length of the lower lip quadrants. Note the asymmetry in the lower lip in the study group pre-treatment. $^{\$}P < 0.05$ (between pre-treatment values); $^{**}P < 0.01$ (before versus after treatment).

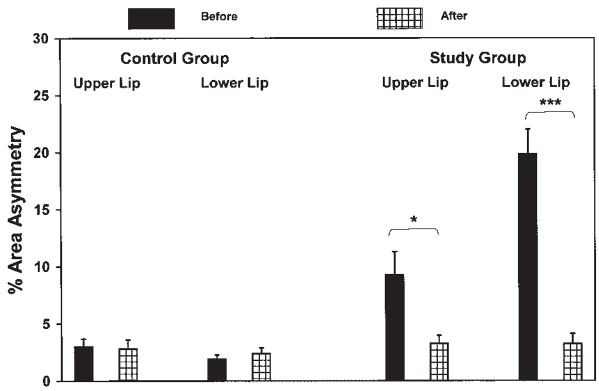

Figure 6 Absolute values of area asymmetry. Note that in the control group asymmetry was up to 3 per cent regardless of treatment. Note also the larger asymmetry of the lower lip compared with the upper lip in the study group and their reduction to control values post-treatment. $^{*}P < 0.05$, $^{***}P < 0.001$ (before versus after treatment).

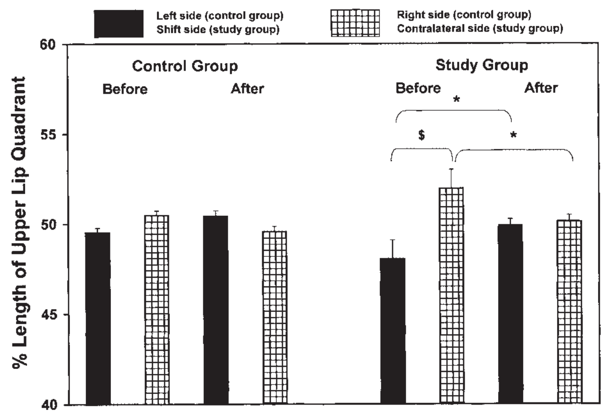

Figure 8 Mean values of the percentage length of the upper lip quadrants. Note the inverse asymmetry in the upper lip in the study group pre-treatment. $^{\$}P < 0.05$ (between pre-treatment values); $^{*}P < 0.05$ (before versus after treatment).

observation that the changes in area in the lower lip of the study group were much larger than those in the upper lip. Asymmetry values in the study group were reduced post-treatment to approximately 3 per cent.

The mean percentage length of each of the two quadrants of the lower lip outline pre- and post-treatment in both groups is shown in Figure 7. In the controls, the mean ratio of lower lip quadrants length pre- and post-treatment ranged between 49.9 and 50.4 per cent. In the study group, a mean ratio of 53.0 to 47.0 per cent was measured between the lower lip quadrants, indicating that the lower lip quadrant on the side of the shift was significantly enlarged in length ($P < 0.05$). The post-treatment ratio was only 50.1 to 49.9 per cent. Figure 8 shows the mean percentage length of the two quadrants of the upper lip. In the controls, the mean ratio of the upper lip quadrants length pre- and post-treatment ranged between 49.5 and 50.4 per cent. In the study group, a mean ratio of 48.0 to 52.0 per cent was measured, indicating that the upper lip quadrant on the side of the shift was reduced in length ($P < 0.05$). The post-treatment ratio was 49.9 to 50.1 per cent. Figure 9 shows the absolute values of asymmetry in length of all patients. In the control group, patients had up to 2 per cent asymmetry in length regardless of treatment. In contrast, those in the study group exhibited mean asymmetry of 6.3 per cent in the upper lip and 8.6 per cent in the lower lip. This finding corroborates the clinical observation that the changes in area in the lower lip of the study group were much larger than those in the upper lip. Asymmetry values in the study group were reduced post-treatment to approximately 2 per cent.

Discussion

Dentoskeletal asymmetries in general, and functional asymmetries in particular, have been the focus of

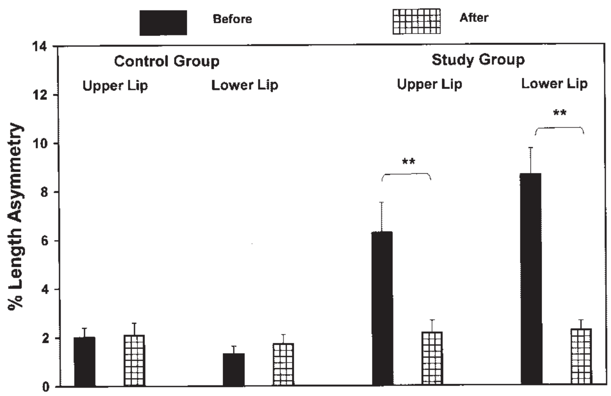

Figure 9 Absolute values of length asymmetry. Note that in the control group asymmetry was up to 2 per cent regardless of treatment. Also note the larger asymmetry of the lower lip compared with the upper lip in the study group and their reduction to control values post-treatment. $^{**}P < 0.01$ (before versus after treatment).

orthodontic interest (Pirttiniemi, 1994; Joondeph, 2000), which encompasses the aetiology of the developing problem and the structural, muscular, and joint adaptations when the asymmetry persists (Bishara *et al.*, 1994; Pirttiniemi, 1998). The muscular and skeletal changes after resolution of the malocclusion have also been reported (Brin *et al.*, 1996). The general consensus is that functional crossbites should be corrected as soon as possible to eliminate the potential for musculoskeletal adaptive changes, or if already present, to reduce them in the future (Mongini and Schmid, 1987).

Lips have varying configurations, shapes, and degrees of thickness. Generally, lip fullness is hereditary, but can also be determined, to a large extent, by the position of the dental arches. It is well known in orthodontics and aesthetic dentistry that in the same patient, anteriorly positioned teeth will create fuller lips compared with a more retruded position. Whatever their shape and volume, they should exhibit bilateral symmetry. This is examined by visually comparing the homologous parts of the lips. In the presence of an anterior unilateral or buccal crossbite extending to the canine area or to the lateral incisor, tooth support to the lips in the anterior segment will not be symmetrical. When the canine is involved the lower lip on the crossbite side will have more pronounced support by the mandibular protruding tooth (or teeth) and will show increased thickness contrary to the upper lip, which lacks that support. In the presence of a functional shift, it is easy to assume that this asymmetry will be accentuated as the displaced mandible pulls the lower lip sideways and the merging of both lips at the commissure is not symmetrical (Figure 1c, e). Future studies are necessary to show which of these two factors contributes more to lip asymmetry. The percentage expression of right and left relevant lip surface area or outline as performed in this study allowed lip symmetry to be estimated objectively in spite of individual lip configuration and thickness. Whilst both lip surface and length demonstrated significant differences between the two halves of each relevant lip in the study group prior to treatment, surface area proved to be a more sensitive tool for measuring lip asymmetry, probably due to the expression of two planes of space.

Lip symmetry should always be examined in the full ICP. In the postural (rest) position, without any tooth contact or in the RCP, the mandible is more centrally located, and lip asymmetry may not be obvious. In this study, a minor asymmetry of up to 3 per cent between left and right surface area or length of the lower and upper lips in the control group was not clinically apparent at the time of examination. However, in the study group the ratio was sufficiently large between the lower quadrants to be easily noted at the initial examination. Upper lip thinning was more difficult to determine due to its smaller volume. Lu (1965) stated that only facial asymmetries greater than 3 per cent are clinically discernible, which is in agreement with the present study. This explains why all patients in the control group, pre- and post-treatment, and in the study group, post-treatment, appeared to have symmetrical lips.

Lip asymmetry can be used as a diagnostic aid. Both professionals and lay-people will be able to recognize a problem when lip asymmetry exists and thus be able to refer young people to seek treatment. This will avoid the future complications mentioned above. Quantitative analysis of the lip area/symmetry is a valuable aid in diagnosis and the evaluation of treatment outcome.

Conclusions

1. Lip surface area and length can be quantitated from clinical photographs and used to measure lip asymmetry.
2. Functional side shifts accompanied by a unilateral crossbite that includes the canine, result in thickening of the lower lip and thinning of the upper lip on the same side. These changes result in measurable lip asymmetry.
3. Elimination of the crossbite and the functional side shift restores lip symmetry both visually and quantitatively.
4. Focus on lip asymmetry can encourage young patients to seek treatment as soon as possible, thus avoiding the dental, skeletal, muscular, and joint complications that may accompany uncorrected side shifts into adulthood.

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