Effects of Twin-block therapy on protrusive muscle functions

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Protrusive mandibular function, including maximum protrusive force and fatigue time, was investigated in 66 children displaying Class II Division 1 malocclusion. Thirty-two children were treated with the Clark Twin-block appliance and the other 34 children served as untreated controls. The observation period was 6 months. Cross-sectional data based on pretreatment records showed that maximum protrusive force ranged from 18.5 N to 160 N, with a mean of 80.3 ± 30.7 N. Maximum protrusive force was significantly higher in males than in females ($P < .001$). The correlation between maximum protrusive force and chronologic age was low ($r = 0.20$) and did not reach significance. Maximum protrusive force in the group of children with disk displacement was not significantly different from that of the group without disk displacement. Comparison of pretreatment and 6-month records in the untreated control group revealed a significant increase in maximum protrusive force ($P < .01$) as a result of normal growth, while the measured change in the Twin-block-treated children did not reach significance. Fatiguing the protrusive muscles did not alter mandibular position in the Twin-block group after 6 months of treatment. The present study does not support the lateral pterygoid hypothesis, as there was no evidence of an increase in mandibular protrusive function after treatment with the Twin-block functional appliance. (Am J Orthod Dentofacial Orthop 2000;118:392-6)

Many studies on functional appliance effects have explored the role of the mandibular protrusive musculature in promoting growth of the condylar cartilage and subsequent lengthening of the mandible, with emphasis on the lateral pterygoid muscle.[1-3] However, the lateral pterygoid muscle is difficult to access beneath the overlying structures. It is not possible to directly palpate the lateral pterygoid muscle clinically,[4] and any attempt to do so poses the possibility of confusion with the sensitivity of other muscles such as medial pterygoid or temporalis muscles.[5,6] Moreover, the study of lateral pterygoid function using an electromyogram is generally invasive and may lead to discomfort, muscle soreness, or jaw stiffness, and occasionally to hematoma or infection.[7]

The objectives of the present study were to investigate the function of protrusive muscles using a new, noninvasive approach, and to test whether these muscles were responsible for mandibular repositioning after treatment with the Clark Twin-block (CTB) functional appliance.

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SUBJECTS AND METHODS

Seventy-one white children, between 10 and 14 years old and involved in a major prospective Twin-block project, agreed to participate in this study of their protrusive muscle function.

All the children had Class II Division 1 malocclusion with clinical appearance of retrognathic mandible, short lower facial height, and overjet greater than 5 mm. None of the children had signs or symptoms of temporomandibular disorders as assessed clinically. Thirty-two children were treated with the Clark Twin-block appliance[8] by the same operator (K.C.); the other 34 children were untreated and served as controls. Bite registration for the CTB construction was made with the mandible positioned forward to incisor edge-to-edge and opened vertically to achieve a posterior interocclusal separation of at least 6 mm. Where an edge-to-edge incisor relationship could not be achieved, the maximum forward posture position was recorded. The initial mean overjet was 9.9 ± 2.2 mm for the CTB group and 8.9 ± 2.2 mm for the untreated control group.

Three children were excluded from the study because they were not able to perform the muscle test properly and another 2 children were withdrawn due to cooperation problems. Therefore, the final sample included 34 children (23 boys and 11 girls) in the control group and 32 children (18 boys and 14 girls) in the CTB group. Protrusive mandibular function was determined from pretreatment recordings (R1) and 6-month recordings (R2) for the control and the CTB groups according to the protocol described below.

The study of protrusive muscle function consisted of measurements of maximum isometric protrusive force and the time to fatigue the protrusive muscles. The muscle test apparatus consisted of a biteplate and a chincup connected to a transducer by a pulley system, all supported by a rigid back plate. Details of the muscle test apparatus have been described elsewhere[9] and will be summarized here.

The children were positioned carefully in a rigid frame apparatus that kept the head and shoulders in a fixed position relative to the protrusive force recording device. The operator manipulated each child's mandible several times to achieve the most reproducible retruded position. Overjet was measured using a millimeter ruler on the biteplate, and this was set as the starting position. The biteplate was then placed on the supporting frame and slid into the child's mouth to stabilize the anteroposterior maxillary position. The biteplate vertical position was adjusted at the supporting frame so that the occlusal line of the maxillary teeth was parallel to the horizontal plane. The children were asked to bite gently on the biteplate with the mandible in the most retruded position. The rigid chincup connected to the transducer through a pulley system was then placed around the child's chin. The protrusive force was displayed by a pen recorder. A fixed 10 N (Newton) load, or tension, was applied to the chincup through the pulley system in order to take up the slack in the system and establish a reference baseline.

Maximum Protrusive Force

The child was asked to "push the lower jaw forward" by sliding along the biteplate as far as possible. However, minimal movement of the mandible occurred due to the inelastic cable connecting the chincup and transducer system. The child was asked to hold his or her lower jaw in the most forward position for 3 seconds and then relax. This protrusive force measurement was done at 30-second intervals a minimum of 4 times or until the force generated during the attempted maximum protrusion was relatively stable. The highest force produced during the test was selected for statistical analysis. A 1-minute rest period was then given for the child to relax before the fatigue test.

Fatigue Test

After the rest period, the child was asked to perform maximum protrusion again, but this time forcefully holding the mandible in the most forward position until the force had fallen below 10% of the initial value. This assumed that fatigue of the protrusive muscles had occurred. The chincup and biteplate were removed immediately after the test. Incisal overjet was recorded using a millimeter ruler at the most retruded mandibular position under the guidance of the operator. The amount of overjet before and after the muscle test was then compared to evaluate any change in mandibular position.

Muscle tests were carried out for the R1 and R2 recordings in both the CTB and control groups. The combined results from the CTB and control groups at the initial recording were analyzed cross-sectionally to describe the characteristics of protrusive force and fatigue time in children with Class II Division 1 malocclusion. Protrusive force and fatigue time between the control and CTB groups were then compared to assess any pre-existing differences.

Longitudinal analysis of pretreatment and 6-month recordings was performed to evaluate the effects of the Twin-block treatment plus growth (in the CTB group) and the effects of growth alone (in the control group) on protrusive force and fatigue time. The effect of fatiguing the protrusive muscles on the stability of mandibular position in children treated with the Twin-block appliance was also assessed. In essence, the fatigue test checked for habitual mandibular forward posturing as a consequence of muscle training by the Twin-block appliance.

Reliability Test

Maximum protrusive force and fatigue time tests were performed twice (4 weeks apart) in a group of 10 children (5 females and 5 males) selected randomly from the experimental group. Although the mean variation due to measurement error was low, 5% for maximum protrusive force measurements and 2% for fatigue tests, individual variability was high, ranging from –33% to 66% for maximum protrusive force and from –53% to 81% for fatigue time.

Statistics

Paired *t* tests were used to compare parametric variables between initial and 6-month recordings and unpaired *t* test for comparisons between males and females. Correlation analysis was used to quantify the strength of the relationships between parametric variables, such as age and force and age and fatigue time. The preset level of significance was .05.

RESULTS

Initial Record (R1)

Maximum protrusive force in the combined CTB and control group of children with Class II Division 1 malocclusion showed a wide variation, as indicated by large standard deviations. Tests of normality revealed slight positive skewness where a few children performed

Table I. Comparison of maximum protrusive force (N) at R1 and R2 in control and CTB groups

	R1	*R2*	*Difference (R2–R1)*
Groups	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*
Control/females (n = 11)	58.4 ± 18.2	87.1 ± 32.1	28.7** ± 27.9
Control/males (n = 23)	87.1 ± 25.3	110.5 ± 37.9	23.4** ± 42.3
Control/total (n = 34)	77.8 ± 26.7	102.9 ± 37.3	25.1*** ± 37.9
CTB/females (n = 14)	70.2 ± 31.0	73.5 ± 25.9	3.2 ± 20.0
CTB/males (n = 18)	92.8 ± 35.1	98.2 ± 27.0	5.4 ± 38.3
CTB/total (n = 32)	82.9 ± 34.7	87.4 ± 28.9	4.5 ± 31.2

Paired *t* test.
**Mean difference between R1 and R2 differed significantly from zero at $P < .01$.
***Mean difference between R1 and R2 differed significantly from zero at $P < .001$.

Table II. Comparison of fatigue time (sec) between R1 and R2 in control and CTB groups

	R1	*R2*	*Difference (R2–R1)*
Groups	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*
Control/females (n = 11)	54.2 ± 22.1	56.6 ± 28.3	2.4 ± 29.1
Control/males (n = 23)	72.7 ± 41.5	62.4 ± 37.1	–8.7 ± 50.5
Control/total (n = 34)	66.7 ± 37.0	60.5 ± 34.0	–5.1 ± 44.6
CTB/females (n = 14)	78.2 ± 37.9	67.6 ± 41.4	–10.5 ± 50.4
CTB/males (n = 18)	66.6 ± 35.1	59.2 ± 24.6	–8.0 ± 39.0
CTB/total (n = 32)	71.7 ± 36.2	63.0 ± 32.9	–9.1 ± 40.6

Paired *t* test, $P > .05$.

with a high magnitude of force. Maximum protrusive force ranged from 18.5 N to 160 N, with a mean of 80.3 ± 30.7 N. Student *t* test revealed that the maximum protrusive force in males was significantly higher than that in females ($P < .001$, Table I). Correlation between maximum protrusive force and chronologic age was low ($r = 0.20$) and did not reach significance. Fatigue time ranged from 17 seconds to 206 seconds, with a mean of 69.1 ± 36.4 seconds. Tests of normality also showed evidence of positive skewness for the distribution of fatigue time in the study. Mean fatigue time in the male group (70.0 ± 38.5 seconds) did not differ significantly from that in the female group (67.6 ± 33.6 seconds).

The mean maximum protrusive force for both boys and girls in the CTB group (82.9 ± 34.7 N) did not differ significantly from that in the control group (74.4 ± 23.5 N). Fatigue time also showed a similar trend, 71.7 ± 36.2 seconds for CTB group and 66.7 ± 37.0 seconds for control group, and the difference was not significant.

Initial vs 6-month Recordings

For the control group, maximum protrusive force at R2 was significantly higher than at R1 (paired *t* test, $P < .001$). Significant increases in average maximum protrusive force were also found within male ($P < .01$) and female subgroups ($P < .01$). Although the maximum protrusive force was also found to have increased in the CTB group, the change did not reach a statistically significant level (Table I). For the fatigue time, paired *t* tests did not reveal any significant differences in either the control or the CTB groups (Table II).

Mandibular Position

After the fatigue test at R1, it was possible to guide the mandible to a more retruded position in 12 of the 66 children (18.2%), 4 females and 8 males. The change in mandibular position was demonstrated by an increase in overjet after the fatigue test. The increase in overjet ranged from 0.5 mm to 3.0 mm (mean, 1.2 mm). These 12 children had incisal overjets greater than or equal to 7 mm. Chi-square analysis revealed no significant differences in the number of children with changed mandibular position between males and females or between control and CTB groups.

DISCUSSION

Protrusion of the jaw can be achieved by the activation of the lateral pterygoid and the superficial masseter muscles.[10] During maximal protrusive force application, other muscles, such as the digastric, medial pterygoid, or temporalis may participate in bracing the condylar head against the articular eminence.[11] Although there is some variation in the insertion of the muscle into the condyle/disk, the lateral pterygoid is the only jaw muscle that inserts directly into the jaw joints and exerts pressure on them.[12,13] Several studies have suggested that activity of the lateral pterygoid muscle is essential for normal condylar growth and that increased lateral pterygoid muscle activity is a prerequisite to the stimulation of increased condylar growth.[1,2,14-17] This is commonly known as the "lateral pterygoid hypothesis." An increase in lateral pterygoid muscle activity associated with an increase in the proliferation of condylar cartilage after the use of functional appliances was reported in monkeys[1,16-19] and in rats.[14] Direct application of the animal findings to human beings, however, is not possible because the temporomandibular areas, including joints and muscles, have different characteristics.[20]

Furthermore, other studies[14-17] have not supported the lateral pterygoid hypothesis. Although the rate of mandibular growth increased with the use of functional appliances, it was not associated with a change in activity of the lateral pterygoid muscle.[21-24] Auf der Maur[21] and Hiyama[22] found that the activity of the lateral pterygoid muscle increased with functional appliance use, whereas Sessle et al[23] and Yamin-Lacouture et al[24] found that it decreased. However, these authors[21-24] agreed that the change in activity diminished shortly after appliance insertion and before correction of the jaw relationship was achieved. Therefore, the morphologic change in jaw relationship does not appear to depend only on the functional stimulation derived from the lateral pterygoid muscle.

In the present study, the lateral pterygoid hypothesis was tested with a different approach. Based on the hypothesis, it could be assumed that the mandible was held in the new position after CTB treatment by means of hyperactivity or contraction of the lateral pterygoid muscle. It was expected that fatiguing the protrusive muscles by continuous isometric protrusion for a long period of time would result in relaxation of the muscles. Consequently, it would be possible to alter the mandibular position from a muscle-controlled position (forward position achieved by muscle contraction) to a structural-control position (with the condyle seated in the glenoid fossa). However, the position of the mandible did not change significantly after fatiguing the protrusive muscles. It appeared that the lateral pterygoid muscle may not be responsible for the new position of the mandible after treatment with the CTB. It is possible that the temporomandibular joint adapted to displacement of the mandible by condylar growth and surface modeling of the fossa.[25]

It is acknowledged that the results of the present study do not represent the activity of the lateral pterygoid muscle alone, but rather a combination of all the protrusive muscles. In addition, functional appliances have been reported to alter the proportion of muscle fiber types in the lateral pterygoid muscle,[26] with the number of fast nonfatigable fibers increased significantly. It is possible that the method in the present study failed to completely fatigue all the protrusive muscles.

Comparisons between pretreatment and 6-month follow-up recordings revealed contradictory results between control and CTB groups. The significant increase of maximum protrusive force in the control group was considered to be a result of normal growth and development. As interindividual variation was large, this may explain why no association between protrusive force and age or stature could be demonstrated when using the cross-sectional data. The results from the present study were very similar to those of a longitudinal study by Braun et al,[27] who found that bite force increased over a 2-year observation period. However, no association of age or stature was found in a previous cross-sectional study.[28] The increase in bite force is hypothesized to reflect an increase in muscle mass, and the difference between males and females is more obvious after postpubertal growth. The role of muscle mass in increasing bite force is supported by other studies.[29-31]

In the present study, a trend toward an increase in maximum protrusive force was also found in the CTB group, but it did not reach a significant level. It was hypothesized that the functional appliance would alter the neuromuscular system. Muscular adaptation can be expressed as alteration in muscle length, reorientation of muscle fibers, or relocation of muscle attachment. It is possible that the lateral pterygoid may shorten as it adapts to a new mandibular position. The net increase in muscle mass due to growth and development in the CTB group could be less than that in the control group. Shortening of the lateral pterygoid muscle as a response to Twin-block appliance therapy has also been demonstrated in monkeys.[24] This shortening may itself cause some loss of force and activity of this muscle.[32]

High individual variation in the measurement of protrusive force in this study should be taken into consideration when interpreting the present results. Alteration of muscle recruitment patterns between sessions has been hypothesized as a contributing factor to the variability. Maximum protrusive force may have been developed by the recruitment of different parts of various muscles and hence, for each defined function, different net forces are delivered. This finding is similar to a recent study by Scutter and Türker,[33] who found different recruitment patterns of jaw muscles when developing defined isometric jaw closing contractions.

Braun et al[28] reported that subjects with TMD symptoms did not exhibit a significantly different maximum bite force than subjects without symptoms, while Marklund and Molin[34] reported a significant reduction of maximum protrusive force in females with TMD symptoms. None of the children in the present study had clinical signs or symptoms of TMD, but painless disk displacement was found in 12 of 40 children during MRI examination.[35] Maximum protrusive force in the group of children with disk displacement (88.7 ± 29.8 N, n = 12) was not significantly different from that of children without disk displacement (87.5 ± 31.9 N, n = 28).

CONCLUSIONS

These results strictly refer to the Twin-block approach and cannot be generalized to other functional treatment procedures. Maximum protrusive force at the 6-month observation was significantly higher than that of the initial recording for the control group ($P < .01$) as a result of growth, but did not reach significance, set at $P = .05$, for the CTB group. It is hypothesized that CTB therapy may have shortened the protrusive muscles and consequently slowed down the increase of muscle force observed in the untreated controls. Fatiguing the protrusive muscles did not alter mandibular position in the CTB group after 6 months of treatment. The findings suggest a lack of habitual forward mandibular posture. Maximum protrusive force in the group of children with disk displacement was not significantly different from that of children without disk displacement.

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