Pressures Exerted By The Buccinator Muscle*

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INTRODUCTION

The muscular environment of the teeth has long been thought to be one of the chief factors in determining the form and maintenance of the human dental arch. This environment has been thought of principally as the tongue on the inside and the lips and cheeks on the outside, modified by certain other forces such as the mutual support given by the teeth to each other, their inclinations and their responses to the functional forces put upon them. The two muscle masses have been considered as being in a state of dynamic equilibrium with each other.

The buccinator muscle has been considered as the chief muscle of the outer group, lying closest to the teeth and described as running a predominantly horizontal course around the denture. It thus would be in a most advantageous position to exert an even, contracting force on the teeth.

Recent observations by Rost and Brodie, '61, indicated that the prevailing concept of the buccinator, as a mere binding sheath, may be an oversimplification so it was decided to test the prevailing hypothesis by placing pressure transducers opposite different areas of the muscle to register any variations revealed by polygraph. They were able to demonstrate differences in the pressures exerted by various areas during function as well as in different classes of malocclusion.

REVIEW OF THE LITERATURE

Modern texts (Gray, '59; Cunningham, '53; Piersol, '30; Wolf-Heidegger, '62) describe the buccinator as a flat, quadrilaterally-shaped muscle lying beneath the buccal mucous membrane. Its fibers were said to run in a predominantly horizontal direction from an attachment on the pterygomandibular raphe in back and from the lateral surfaces of the maxilla and mandible opposite the molar teeth. At the corner of the mouth the most superior and inferior fibers were said to continue into their respective lips while the middle fibers decussated, those from the upper going to the lower lip and those from the lower going into the upper lip. A search of the anatomical literature on the subject reveals that this has not always been the accepted view.

The earliest mention of the buccinator that the authors could find was that by Galen, 177 A.D., who apparently dissected it from the mouth side. He did not comment on the direction of its fibers. De Ketham, 1493, portrayed them as horizontal. In 1510 da Vinci described two slips joining the muscle to the orbicularis oris. Versalius, 1555, had the fibers radiating from the corner of the mouth and running backward to the zygoma beneath the masseter muscle.

Although Bartholinus, 1651, and Celsius, 1657, illustrated the area, they did not indicate the course of the fibers of the muscle but Dionis, 1701, gave them an oblique direction. In 1723 Keill and in 1730 Cheselden gave as

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origins of the muscle the coronoid process and side of the mandible; and Albinus, 1744, called attention to the horizontal direction of the fibers. With their description Heister, 1752, and Winslow, 1782, agreed.

The first mention made of an attachment to the pterygomandibular raphe was by Munro, Winslow and Innes (1784) who called it the sphenoid tendon between the jaws. This structure does not seem to be mentioned again until 1810 when it reappeared in "The London Dissector". In the interim, however, Cheselden, 1806, and Hooper, 1809, again called attention to the coronoid origin.

From 1809 to 1851 there seemed to be rather general agreement on the horizontal course of the fibers, on coronoid and sphenomandibular origins and on attachment at the corners of the mouth. MacLise (1851) described for the first time a vertical arrangement of fibers running to the side of the maxilla but this apparently escaped notice because it was not until 1918 that the vertical fibers are shown in the 20th edition of Gray's text. Curiously enough, they are not shown in later editions but are illustrated in Grant's Atlas of 1943.

Rost and Brodie, '61, published a brief communication calling attention to fine groovings on artificial dentures and on fillings in the buccal surfaces of natural teeth which had been repeatedly observed by one of them (Rost) in the course of a long practice. The groovings seemed to be associated with tenseness and/or hyperactivity of the musculature of the face. The variation of their courses in different individuals led to a questioning of the correctness of the description of the buccinator muscle found in present day texts on human anatomy.

The dissection of 200 cadavers by Ransford indicated that the organization of this muscle was not as simple as it had come to be thought. Nothing was found that had not been seen by a few individuals in the past, but none had described all parts of the muscle.

The Buccinator Muscle

Ransford's dissections (Figure 1) revealed that the main part of the muscle is a heavy fasciculus of horizontal fibers which are attached by dense fibrous connective tissue just above the external oblique line to the lateral surface of the mandible. These fibers pass inside the coronoid process, cross the superior border of the mandible, largely unattached, and run to the pterygomandibular raphe. From their lowest point of attachment at the end of the mylohyoid line the fibers diverge as they attach to the raphe, the higher spreading out fanlike on the infratemporal surface of the maxilla. This gives these fibers a decided upward and backward obliquity. If a wad of cotton or gauze is placed in the vestibule of the mouth and the cheek distended, these fibers are seen to become more vertical as the corner of the mouth is approached. Before they reach the commissure, however, they seem to be reflected back somewhat into a border of greater thickness than the muscle behind them.

Just anterior to the above-mentioned border there is a triangular-shaped interval that is totally devoid of muscle and in which mucous membrane covering the maxilla can be seen. The anterior boundary of this area is formed by the caninus and incisivus labii superioris muscles. The vertical fibers of the buccinator which form the fold of the posterior boundary travel downward and forward into the lower lip. A few of the horizontal fibers lying near the middle of the muscle, or the superior part of the horizontal fasciculus, pass to the upper lip while the more inferior fibers of this fasciculus pass to the lower lip.

Of great interest was the recent veri-

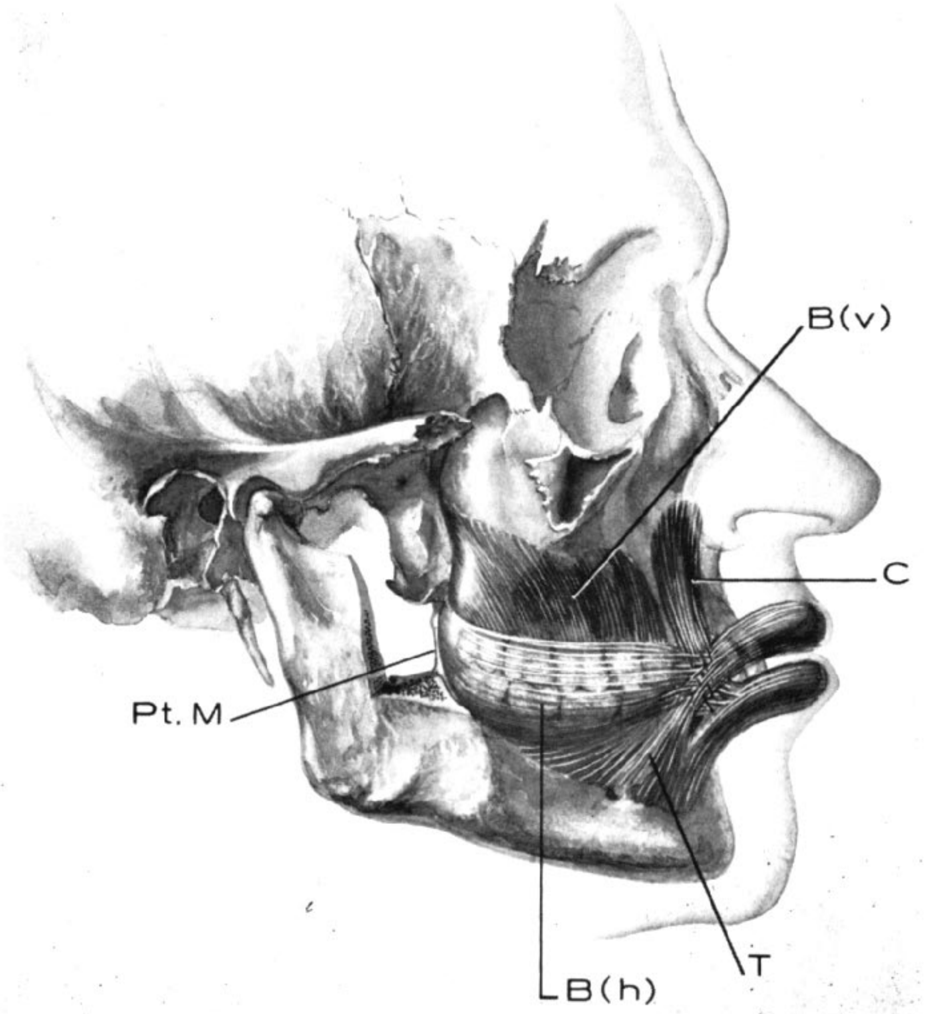


Fig. 1 The buccinator muscle as revealed by Ransford's dissection of 200 cadavera. Bv, vertical fibers. Bh, horizontal fibers. C, caninus. T, triangularis. Pt. M, pterygomandibular raphe.

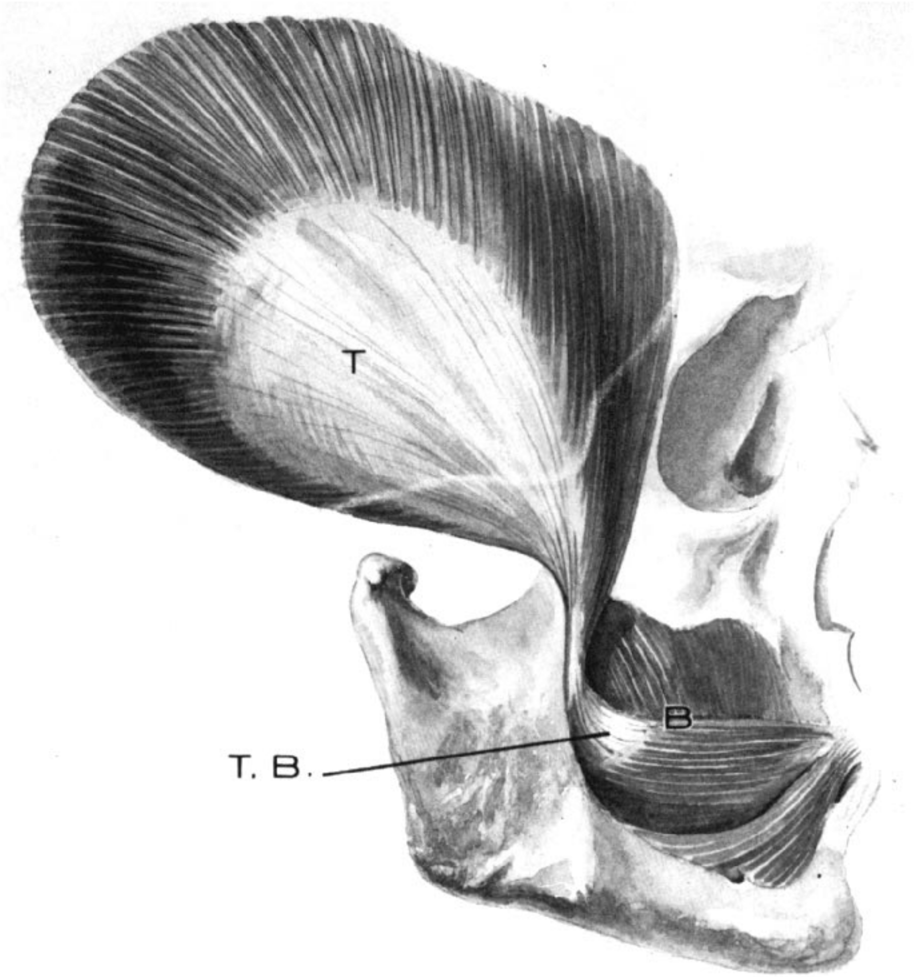


Fig. 2 The temporomandibular band as revealed by Ransford's dissection of 200 cadavera.

fication of the observation of some of the earliest writers regarding the coronoid point of origin of the buccinator muscle. Recent writers have found this connection but they have described it somewhat differently and have ascribed to it a different function. According to these men and the more recent work by Ransford and Takagi (Figure 2), a tendinous band is given off the anterior portion of the tendon of the temporalis muscle. It runs downward, forward and medialward to spread out in the buccinator muscle. According to Gaughran, '57, it would have the function of pulling the buccinator away from the last molar teeth when the jaws were closing.

Of recent years the attention of certain clinicians and investigators, notably the orthodontist and those concerned with cleft palate and speech deviations, has been drawn toward the musculature of these oral regions. Electromyography, manometric and strain-gauge studies have been undertaken in attempts to measure the forces exercised by the tongue, lips and cheeks.

Electromyographic studies to detect the electrical response in muscle were reported as early as 1908 by Dunn, Bennett and McIntyre. Hill, '21, studied the energy in electrical changes in muscle and nerve. Clark, '31, and Smith, '34, continued the work on innervation ratios and potentials in single motor units.

Applications to the dental region were begun in 1938 by Ebert on the masseter muscle. In 1940 Larson studied muscular activity in mastication. Stimulation of the muscles of mastication was also studied by Brekhus, Armstrong and Simon, '41.

Since these earlier works studies on a wide variety of problems have been conducted by numerous investigators including Cutbort and Denslow, '45; Movers, '49, '50, '56; Carlsöo, '52; Tulley, '53, '56; Schlossberg, '53; Perry, '53; Basil and Moyers, '60; Barnick and Ramfjord, '62; Story, '62; Woelfek, Hickey and Allison, '62.

Several investigations have been made to determine antagonistic muscle pressures of the tongue and lips, Alderisio, '53; Kydd, '56, '57, '62; Winders, '56, '58; Abrams, '58. Other work involving strain gauges has been done on plastic and metal denture bases and Stromberg, '55, published findings on the pressure exerted on the tissues by artificial dentures. More recently attempts have been made to study the the movement of teeth under masticatory stresses, Schöhl, '60.

There is no report in the literature of studies on the buccinator muscle alone. This is probably due to the almost universally held concept that this muscle encircles the dental arches and thus exerts equal pressures throughout its extent.

MATERIALS AND METHODS

In this study the resistance bridge transducer was chosen as a method for measurement of exerted pressures as one which had the most desirable properties. Among these can be mentioned: accuracy and linearity over a wide range of pressures, compact size, comfort to the patient, simplicity of operation and ready duplication.

The general principle involved was the conversion of pressure to an electrical potential. This was accomplished with the transducer which converted the pressure supplied by the muscle into a measurable electrical potential.

The transducer consists of two components: the elastic member and the resistive wire on bonded strain gauge. The pressure was applied to the elastic beam which was deformed at its free end. On this beam the gauge or resistive wire was cemented. This type of gauge depended on the changes in electrical resistance of a metallic wire when subjected to mechanical distortion or stretch. In a common form, this gauge consists of resistive wire wound back and forth to form a grid bonded between thin pieces of paper. Strain placed on the elastic member distorted the resistance wire of the bonded strain gauge and thus altered its resistance. The bonded strain gauge was incorporated as one arm of a Whetstone bridge. The other three arms were fixed resistors of the same value as the bonded gauge. The resistance change created in this gauge by the applied pressure served to unbalance the previously balanced bridge and caused a small potential to appear at the output of the bridge. This potential bears a direct linear relation to the applied pressure. It was amplified and recorded.

Since it is likely that only a few readers of this report will be interested in undertaking similar investigations, space will not be taken here to describe the fabrication of the transducers. Detailed description can be obtained by writing to the authors. Only the method of locating the transducers in the mouth will be described.

Upper and lower alginate mouth impressions were made with special care exercised to reach the limits of the vestibule. The models made from these were trimmed and held together with a "C" clamp. Small swab sticks were placed from one cast to the other in the area to be measured and secured by wax. The area was the mesiobuccal cusp of the maxillary first molar and perpendicular to the plane of occlusion. The first gauge was placed as high as possible in the maxillary vestibule, the second at the occlusal plane, and the third as low as possible in the mandibular vestibule. This was duplicated on the opposite side and in both cuspid regions. The gauges were placed 3 mm from the tooth surface with the leads as close to the casts as possible and luted to position with wax. Care was used to lute only those areas which would not be covered by acrylic. Quick cure acrylic was used to form the template.

The template was cured in boiling water for 20 minutes. After removing the casts, the templates were trimmed, care being taken not to injure the gauges or to expose or damage the leads. The acrylic was kept as close to a thickness of 1 mm as possible. The interproximal areas and periphery were trimmed for patient comfort. The template was polished and buffed and the gauges coated with liquid rubber. The gauges were also color coded for easier handling and recognition. The final step in gauge preparation was the incorporation of plugs to connect them with a component box in which those elements necessary for completion of the circuit were placed. To connect the mouth unit with the component box shielded plugs were used with three gauges attached to each plug.

Following tests with the fixed gauges, another template was fashioned, this one equipped with orthodontic twin-wire brackets on which appropriate caps could be slid. This made it possible to use the gauges with other templates or other subjects. A few modifications were found necessary with the removable type of device. The major modification was the mounting of the elastic arm and gauge on a twin wire cap. In addition, holes were placed in the template for convenient handling and tying down the immediate wires to insure against movement.

In order to determine whether it was possible to detect the presence and activity of the temporal-buccinator band it was necessary to fabricate a template that would allow the opening and closing of the jaws as in chewing. This was accomplished by covering the teeth and vault of only the upper model. The gauges were placed opposite the first molar and distal to the second molar. The template fitted snugly and per-

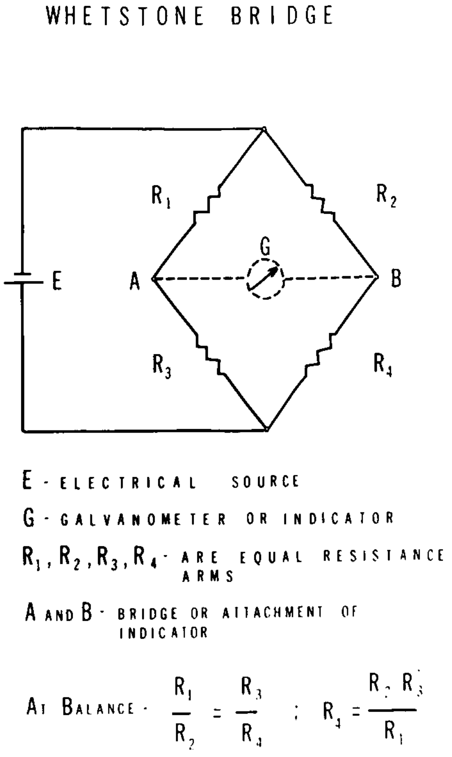


Fig. 3

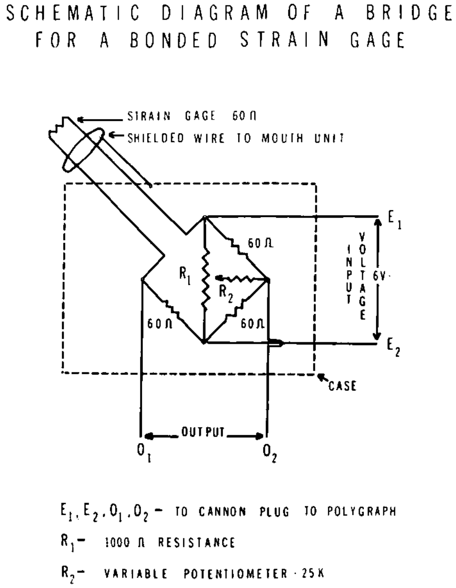


Fig. 4

mitted all chewing movements without displacement.

A metal box was next utilized to allow placement of accessory components. These were the three resistors necessary to complete the Whetstone bridge and a balancing circuit. In Figure 3 a Whetstone bridge is illustrated. Roberts, '51, described it in detail in similar applications.

A schematic diagram of the circuit used in this work may be seen in Figure 4. The only changes from Figure 3 were the inclusion of a variable potentiometer and a 1000 ohm resistor which allowed exact balancing of the system. All resistors were precision wire wound with 1% error. All wiring was color coded for ease in tracing circuits, and all leads were grounded to the case. To complete this system the leads from this box were fitted with plugs to connect to the polygraph.

The final elements in the system were the preamplifier, driver amplifier, and electronic recording system. The Model 5 Grass Polygraph was used with a Model 5P1 low level D.C. preamplifier.

In brief, a resume of operation follows. The polygraph was allowed to warm up for at least one half hour to insure drift-free operation.

All standard balancing and adjustment procedures necessary for the Grass instrument were executed. The sensitivity of the preamplifier was then adjusted so that 100 millivolts gave a pen deflection of one centimeter. This sensitivity was consistent with the pressures encountered in the mouth as determined in preliminary experiments.

Gathering of Data

Data were gathered from recordings taken on four individuals with normal occlusion, one of whom had a protrusive dentition; one who had Class II, Division 2: and one who had Class III type Angle malocclusion. One additional set of recordings was made on an individual with normal occlusion with gauge placement at the first bicuspid region. All subjects were white males between 25 and 30 years of age. Removable gauges were employed on all.

At the beginning of each study the polygraph and the bridges were calibrated. The template and gauges were placed in the mouth to allow all components to reach body temperature. Since the mouth temperature is notably stable and no foreign elements were introduced, extra systems of temperature compensation were not necessary. With the muscles at rest the recording stylus from each gauge was returned to its baseline. Any pressures placed on the gauge at rest were cancelled; thus the recordings represented relative pressure changes of areas of the muscle.

The first series of polygraph readings were recorded using the fixed and removable gauges. Readings from the gauges were made on the same patient. The gauges were identically placed for both recordings. Findings showed consistent results from both the fixed and removable gauges, thus proving the accuracy of the removable type of gauge.

Vertical bar graphs were constructed from the polygraph records (Fig. 5). These were magnified proportionately to facilitate easier interpretation. All the normal occlusion cases fell essentially in the same pattern varying only in degree (Fig. 6). The greatest fluctuation occurred in the readings of counting, facial movements and the removal of a seed. The readings taken of the heavy pressure, swallowing and smiling were considered the most stable for comparison.

A vertical bar graph was likewise constructed from the polygraph readings from the temporobuccinator band tests. This showed a striking contrast (Fig. 7).

Each subject was thoroughly instructed in the acts to be performed before recordings were attempted. Among those included were: strong tensing of the cheek and lips with the teeth in occlusion, sucking, swallowing, smiling, general facial movement, counting from one to ten, and movement to remove a seed from the upper flange of the template.

One of the authors was the sole subject for the study of the temporobuccinator band. He executed all of the acts noted above in addition to opening and closing his mouth as though chewing. Here also no correction of the baseline was made.

RESULTS

In the normal occlusions the reading at the first molar taken at the occlusal level was always predominant. The reading taken from the lower vestibule fell at about half that of the superior or one quarter of the occlusal reading.

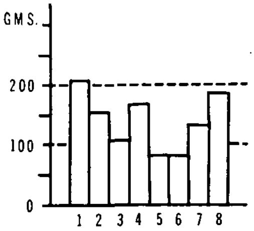
In the normal occlusions taken at the cuspid-first bicuspid region a striking contrast was noted. The reading at the occlusal plane dropped to less than half of the molar reading. The maxillary vestibular reading doubled, while the lower molar reading increased very slightly.

The readings from the protrusive denture at the first molar were essentially the same as the normal but during swallowing dropped more rapidly at the occlusal and lower vestibular levels. During strong tensing, the highest reading was from the gauge at the occlusal level with the lower reading half of this and the superior reading the smallest.

A Class II, Division 2 malocclusion was recorded for comparison. In this case the superior readings were the greatest, more than double those in the normal cases. The reading at the occlusal level was the smallest and the inferior remained essentially unchanged.

In a Class III case the three readings

KEY TO BAR GRAPHS



1 - HEAVY PRESSURE, TEETH OCCLUDED
2 - SWALLOW
3 - SMILE
4 - MAXIMUM } COUNT 1 TO 10
5 - MINIMUM
6 - MINIMUM } FACIAL MOVEMENTS
7 - MAXIMUM
8 - REMOVE SEED FROM UPPER FLANGE

GRAPH TAKEN FROM NORMAL 1st MOLAR READING AT OCCLUSAL LEVEL

Fig. 5

PRESSURE MEASURMENT AT THE 1st MOLAR AND BEHIND THE 2nd MOLAR ON THE OCCLUSAL LEVEL

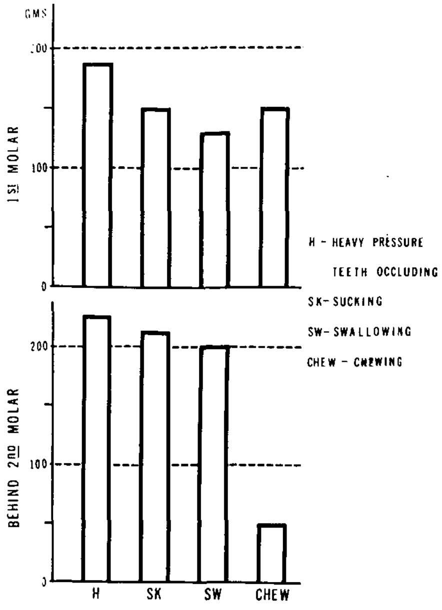


Fig. 7

RELATIVE PRESSURES OF THE BUCCINATOR MUSCLE

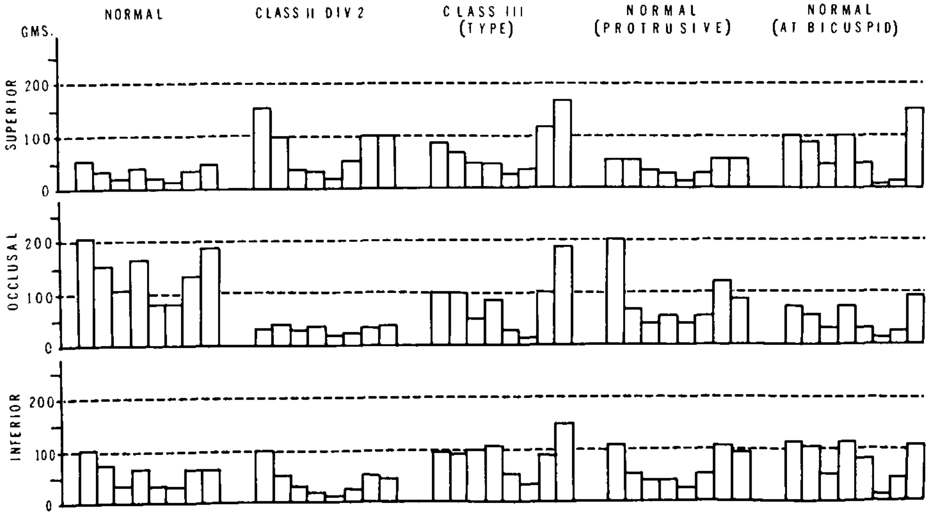


Fig. 6

fell much closer together. The inferior and occlusal levels were essentially equal while the superior fell slightly lower. In short, a consistent pattern was found in all of the normal cases. The patterns in malocclusions varied from this and from each other.

Gauges on the template that had been designed to detect differences in pressures at the first molar and behind the second molar were placed horizontally at the level of the occlusal plane. The same facial movements were used with the addition of opening and closing the jaws.

The readings behind the second molar were consistently higher in heavy pressure, sucking and swallowing, but dropped to less than one-quarter of the heavy pressure in mouth closing. On the other hand, the readings at the first molar, which began slightly below the posterior readings and decreased during sucking and swallowing, increased during mouth closing.

A definite drop in pressure behind the second molar during closing was shown by test with an unadjusted baseline.

DISCUSSION

The results, as judged from the proportionately magnified readings shown by the bar diagrams, indicated that the method of collecting data by transducers would demonstrate small differences of pressure. Furthermore, such readings could be duplicated consistently.

Readings were taken with gauge placement on the occlusal level behind the second molar, at the first molar, and at the first bicuspid region for comparison.

The readings taken with gauge placement at the first molar and behind the second molar varied in degree except for a significant drop in jaw closure. This drop can possibly be correlated with the temporal slip described by Hovelacque, Gaughran, Takagi and Ransford. A decrease in pressure in this area could be expected if the temporal slip functions in chewing to prevent biting of the cheek.

Comparing the three gauges placed at the first molar and the first bicuspid region, the occlusal gauge of the bicuspid region showed a drop in pressure. The inferior gauge showed a slight increase which demonstrated the predicted pattern of the horizontal component of the buccinator going into the lower lip. The upper bicuspid reading was slightly less than the lower reading but higher than the reading on the molar. This was interpreted as the crossing of some of the horizontal fibers to the upper lip. There were minor variations seen between the sides but the pattern was consistent in repeated tests. It is interesting to note that a similar heavy pressure reading was obtained with a manometric system in a pilot study. This system consisted of a similar template but was constructed with balloons mounted and connected to mercury manometers.

There were greater variations exhibited in the facial movements acquired through training, e.g., smiling, counting, etc. The basic movements of sucking, swallowing, strong tensing were more consistent and more striking by comparison.

Standardization was necessary for the validity of the conclusions. Differences in gauges, templates, and materials have had profound effects on the results of the experiments. Correcting the gauges to make the readings relative rather than absolute, and care in construction helped to minimize such errors.

The sample of patients was too small to make valid conclusions but it did indicate patterns. All of the cases with normal occlusion showed the same pattern. The patients with malocclusion showed variation from this pattern. It would be interesting to follow patients under orthodontic treatment to discover if the muscular pressure changes with treatment.

SUMMARY

A study was undertaken to determine whether the buccinator functioned as a sheath, exerting equal tensions throughout its full extent, or whether it exhibited area differences.

The method involved the use of pressure transducers, strain gauges incorporated in acrylic templates and located opposite various areas of the muscle. The areas were: the canine-premolar area, the first molar area, and the area posterior to the last molar in occlusion. At the first two areas a series of three vertically arranged gauges were employed in order to study tensions at the top and bottom of the vestibule and at the level of the teeth.

The gauges used to determine differences at the first molar and at the back of the vestibule were arranged horizontally at the occlusal level of the teeth.

Tests were run on four individuals with normal occlusion and on one Class II and one Class III malocclusion. These revealed a consistent pattern in the normal with the occlusal level showing the highest pressures, the lower vestibule next, and the upper vestibule the lowest.

In the Class II malocclusion the greatest pressure was found in the upper vestibular region, the lower vestibule was intermediate and the occlusal level the least. In the Class III malocclusion the lower vestibule and occlusal levels demonstrated approximately equal pressures and the upper vestibule the least.

The transducer method appears to be sufficiently sensitive to demonstrate differences in pressure exerted by various areas of the buccinator muscle.

Normal occlusions appear to be associated with a rather consistent pattern of buccinator pressures. In those cases the heaviest pressures are exerted against the teeth, the lower vestibular pressures were intermediate and the upper vestibular pressures the least. In Class II malocclusion the heaviest pressures are in the upper vestibular area and in Class III they are at a lower level involving both the teeth and lower vestibule.

Since both the Class II and Class III malocclusions were of a mild degree it seems reasonable to expect that the contrast between them and the normal would increase with the severity of the malocclusion.

The differences in the readings at the first molar and in the posterior part of the vestibule during closing movements of the jaws would seem to indicate that the temporobuccinator band does indeed act to withdraw the cheek from between the teeth during jaw closure.

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