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Article

Correlation between masseter muscle activity and maximum bite force among various facial divergence pattern.

Correlación entre la actividad muscular masetera y la fuerza máxima de mordida entre varios patrones de divergencia facial.

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Abstract: Objective: To comparatively assess electromyographic (EMG) activity of masseter muscle and maximum bite force among various facial divergence pattern. To compare bilateral variation therefore derive the clinical importance changes in masseter EMG activity. Materials and Methods: The sample size comprised of 90 subjects, age ranging from 16-25 years. They were further classified under three subgroups-normodivergent, hypodivergent and hyperdivergennt based on the cephalometric values. Tekscan Flexiforce B201H sensor along with the associated software was used to record the bite force. The EMG of the superficial masseter muscle was recorded using Biotech Neurocare 2000 surface electromyography machine. The muscle activity was recorded bilaterally from the superficial masseter. The data obtained were statistically analyzed using ROC curve at p<0.05. Results: The bite force of the Hypodivergent group (571.83N±36.65) was more than the Normodivergent (387.26±27.20) and Hyperdivergent groups (373.21N±29.23). The EMG recording of masseter muscle activity in Hypodivergent group was significantly higher than Normodivergent and Hyperdivergent groups. (p-value= <0.01). A significant correlation existed between masseter activity and bite force. Conclusion: The bite force of Hypodivergent jaw base individuals is highest followed by Normodivergent and least in Hyperdivergent individuals.The strong correlation between the muscular activity and the bite force is definitely a contributor to the anchorage value during treatment by fixed Orthodontics.

Keywords: Masseter muscle; bite force; electromyography.

Resumen: Objetivo: evaluar comparativamente la actividad electromiográfica (EMG) del músculo masetero y la fuerza de mordida máxima entre varios patrones de divergencia facial. Para comparar la variación bilateral, por lo tanto, derive la importancia clínica de los cambios en la actividad EMG del masetero. Materiales y métodos: El tamaño de la muestra comprende 90 sujetos, con edades comprendidas entre 16 y 25 años. Además, se clasificaron en tres subgrupos: normodivergente, hipodivergente e hiperdivergénico según los valores cefalométricos. Se usó el sensor Tekscan Flexiforce B201H junto con el software asociado para registrar la fuerza de mordida. La EMG del músculo masetero superficial se registró utilizando la máquina de electromiografía de superficie Biotech Neurocare 2000. La actividad muscular se registró bilateralmente a partir del masetero superficial. Los datos obtenidos se analizaron estadísticamente utilizando la curva ROC a p<0,05. Resultados: la fuerza de mordida del grupo hipodivergente (571.83N±36.65) fue mayor que la de los grupos normodivergentes (387.26±27.20) y los hiperdivergentes (373.21N±29.23). El registro EMG de la actividad muscular masetera en el grupo hipodivergente fue significativamente más alto que en los grupos normodivergente e hiperdivergente. (valor de p=<0.01). Existía una correlación significativa entre la actividad del masetero y la fuerza de mordida. Conclusión: la fuerza de mordedura de los individuos hipodivergentes de la mandíbula es más alta seguida por la de Normodivergent y menos en los individuos hiperdivergentes. La fuerte correlación entre la actividad muscular y la fuerza de mordedura definitivamente contribuye al valor de anclaje durante el tratamiento con ortodoncia fija.

Palabras Clave: *Músculo masetero; fuerza de mordida electromiografía.*

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INTRODUCTION.

It is expected that the morphological structures and the functional pattern of the craniofacial system should be in balance. In the era where esthetics is given utmost importance, orthodontic therapy fail to emphasize on the functional efficiency and structural balance of the orofacial structures. Facial growth and orthodontic and Dentofacial orthopaedic treatment is highly influenced by masticatory muscles. In orthodontics it is fundamental to understand the function of these muscles and its relationship with the craniofacial morphology.

Maximum bite force has an influence on the masticatory muscle activity and the function of the masticatory system.[1,2,3] Since divergence pattern has muscular variation which influences the facial morphology, bite force can differ in different individuals. Various studies have shown the effect of muscle activity on the growth pattern of the jaws. The cause-effect relationship is still debatable; whether muscle activity influence growth pattern or vice versa has not yet been established.

According to the concept of muscular anchorage, the facial type described by morphology reflects a particular underlying muscular pattern.[4] In brachyfacial pattern where the musculature is strong, the teeth are controlled with natural anchorage whereas in dolichocephalic patients there is less muscular anchorage. Weaker musculature is unable to resist molar extrusion and bite opening effects of orthodontic treatment.[5]

The purpose of this study was to comparatively assess the EMG recordings of masseter muscle and bite force in Normodivergent, Hypodivergent and Hyperdivergent individuals.

MATERIALS AND METHODS.

A cross sectional clinical study comprising of patients reporting to the Department of Orthodontics and Dentofacial Orthopaedics, S.D.M College of Dental Sciences, Dharwad during the study period of 6 months (2015-2016) was conducted. Ninety subjects, age ranging from 16-25 years formed the study sample. Before proceeding with the study approval from the institutional review board and Ethical Committee and informed consent from the subjects was obtained. Records in the form of photograph, impressions and radiographs were taken. Lateral cephalogram was taken for each patient and the divergence pattern was assessed based on the cephalometric values: (Table 1)

Inclusion Criteria:

1) Skeletal Class I relationship, FMA angle (Tweed's analysis)[6]

i. < 20º for Hypodivergent,

ii. 25º+ 5º for Normodivergent

iii. >30º for Hyperdivergent patients

2) Straight or mild convex/concave profile (Nonsurgical cases ANB range [Steiner's analysis][7] 2º to 5º).

3) Full complement of teeth from central incisor to second molar in all the four quadrants.

4) Age group 16-25 years.

Exclusion Criteria:

1) Severe Class II and Class III malocclusion patients.

2) Severe convex or concave profile (ANB<2º or >5º).

3) Any missing teeth, crowns, bridge prosthesis and Implants.

4) Decayed and not restored teeth.

5) Any TMJ or muscular abnormalities as reported by patients or identified on clinical examinations.

6) Skeletal and dental asymmetry

The following records and data were collected:

Bite force recording:

Bite force was recorded using Tekscan Flexiforce B201H sensor along with the associated software. Silicone putty impression material with 1mm uniform thickness was placed around the sensor to prevent distortion. Strict sterilization protocol was followed and the sensor was wrapped in cellophane sheet for every patient. The patient was asked to sit upright on the dental chair and the head was positioned so that the Frankfort horizontal plane was approximately parallel to the floor. The patient was asked not to change the position while biting on the sensor. When relaxed the patient was asked to perform 100% maximum voluntary clenching. Bite force was measured on the mesiobuccal, mesiolingual, distobuccal and distolingual surfaces of the first and second molars and on the buccal and lingual cusps of the first and second premolars. Readings of the bite force were recorded in Newton (N).

EMG recordings of superficial masseter muscle

Biotech Neurocare 2000 surface electromyography

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machine was used to records the EMG of the superficial masseter muscle at the Department of Physiotherapy, SDM College of Medical Sciences and Hospital, Dharwad. The EMG recording was conducted by the EMG equipment specialist operator who was not informed regarding the divergence pattern.

The EMG recording was done with subject in supine position. The electrode sites were scrubbed with alcohol to reduce skin resistance. The position of the masseter muscle was determined when the subject clenched teeth together. The active electrode was placed at the center of the masseter muscle just below the zygomatic arch, reference electrode was placed inferior to the active electrode with an inter-electrode distance of 1cm. The ground electrode was placed in the arm. The muscle activity was recorded bilaterally from the superficial masseter during minimum occlusion (MO) and maximum voluntary clenching (MVC). The EMG protocol was determined as two sets of function separated by 2 minutes of rest.

Statistical methods

The data obtained were statistically analyzed using ROC curve to correlate maximum bite force and EMG activities of masseter muscle among various facial divergence pattern. The statistical significance was kept at $p<0.05$.

Table 1. Divergence pattern based on cephalometric values.

	FMA	SN-GoGn	Jarabak Ratio	Bjork Sum	Gonial Angle
Hypodivergent	<20º	<29º	>64%	<390º	<1220
Normodivergent	25º	32º±3º	62%±2%	396º±6º	128º±6º
Hyperdivergent	>30º	>35º	<60%	>396º	>134º

FMA: Frankfort-mandibular plane angle. **SN-GoGn:** Sella nasion-gonion/gnathion plane angle.

Table 2. Descriptive statistics of bite force and EMG at MO and MVC in the three groups.

	Group					
	Normo-divergent		Hypo-divergent		Hyper-divergent	
	S.E	S.D	S.E	S.D	S.E	S.D
EMG average MO	7.50675	41.11617	1.63014	8.92866	1.58067	8.65766
EMG average MVC	9.45860	51.80687	12.63935	69.22857	20.10488	110.11899
Total Bite Force	**1.67161**	**9.15578**	**1.69868**	**9.30406**	**.82232**	**4.50402**

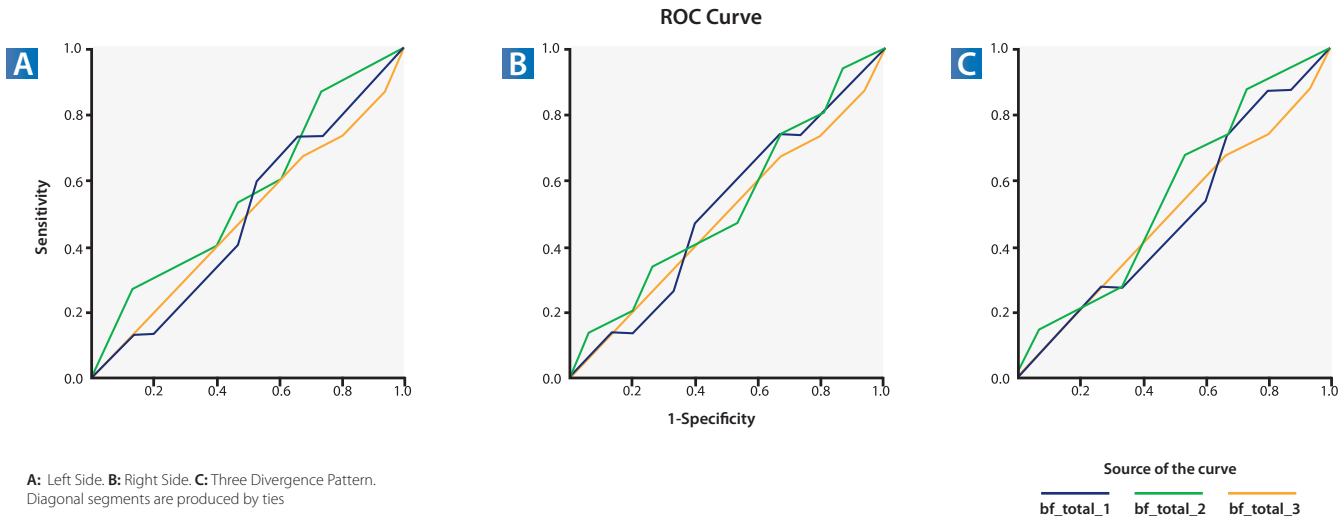
EMG: Electromyography**. MVC:** Maximum Voluntary Clenching. **MO:** Minimum Occlusion.

Table 3. Descriptive analysis of all three groups (Normo, Hypo, Hyper) with respect to total.

	Group					
	Hyper-divergent		Hypo-divergent		Normo-divergent	
	Standard Error	Standard Deviation	Standard Error	Standard Deviation	Standard Error	Standard Deviation
Bite force Left	.71492	3.91576	1.93910	10.6208	1.79553	9.83451
Bite force Right	.98111	5.37378	2.02511	11.0920	1.84241	10.0913
EMG Left MVC	39.8556	29.3285	12.4486	68.1837	9.90926	542752
EMG Right MVC	5.35464	29.3285	12.9359	70.8528	10.7765	59.0254
EMG Left MO	1.45394	7.96355	2.54722	11.4752	7.66685	41.9930
EMG Right MO	1.73295	9.49178	2.54722	13.9517	7.85741	43.0368

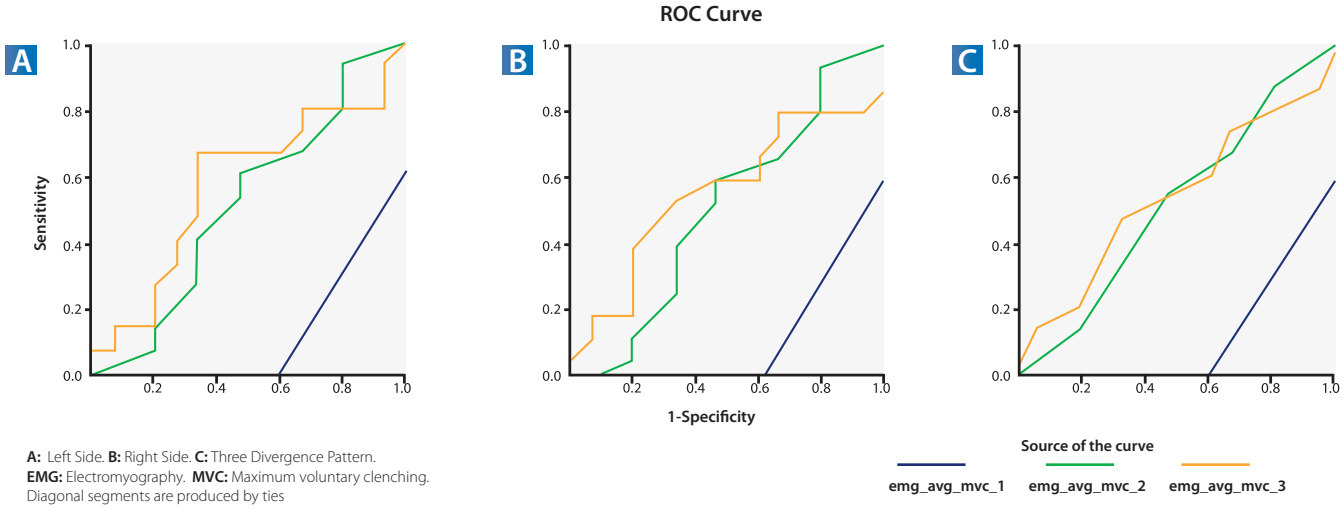
EMG: Electromyography**. MVC:** Maximum Voluntary Clenching. **MO:** Minimum Occlusion.

Figure 1. Comparison of total Bite Force.



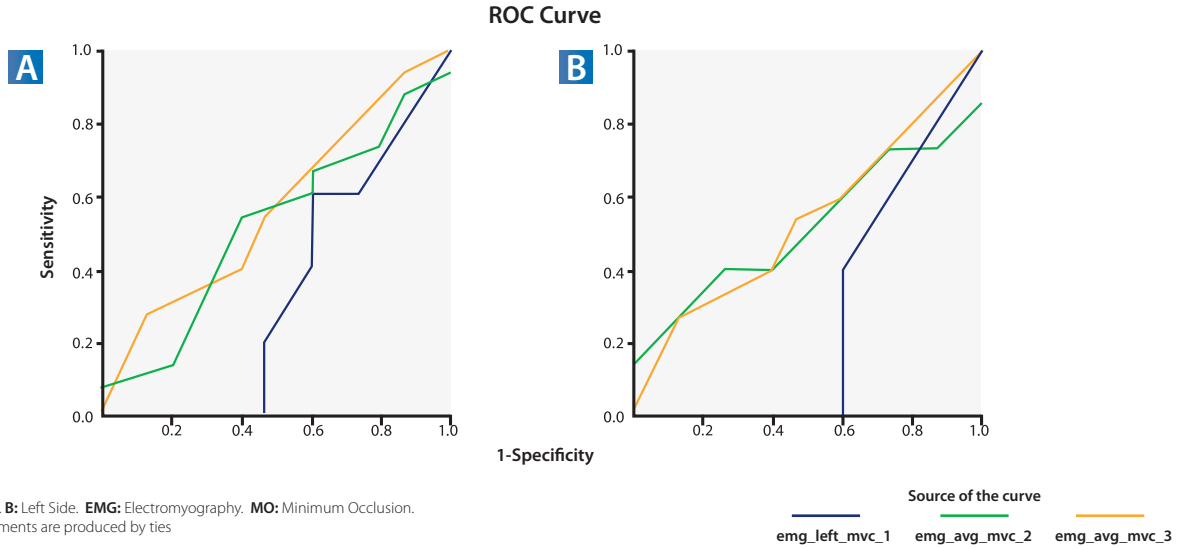
A: Left Side. **B:** Right Side. **C:** Three Divergence Pattern.
Diagonal segments are produced by ties

Figure 2. Comparison of three groups (Hypo, Normo, Hyper) with respect to EMG at MCV, average, left side and right side.



A: Left Side. **B:** Right Side. **C:** Three Divergence Pattern.
EMG: Electromyography. **MVC:** Maximum voluntary clenching.
Diagonal segments are produced by ties

Figure 3. Comparison of three groups (hypo, normo, hyper) with respect to EMG at MO.



A: Right Side. **B:** Left Side. **EMG:** Electromyography. **MO:** Minimum Occlusion.
Diagonal segments are produced by ties

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RESULTS.

Table 2 shows the descriptive statistics of bite force and EMG at MO and MVC in the three groups.

Table 3 shows the descriptive analysis of all three groups (Normo, Hypo, Hyper) with respect to total BF (right+left) and EMG avg (right+left).

Bite force analysis

The bite force of the hypodivergent group (571.83N ±36.65) was more than the normodivergent (387.26±27.20) and hyperdivergent groups (373.21N±29.23).

The total bite force (right+left) between Normo-divergent and Hyperdivergent groups was statistically insignificant (p>0.05).

The findings were statistically significant between Hypodivergent and Hyperdivergent group (p-value=<0.01) and between Normodivergent and Hypordivergent groups (p-value=<0.01). (Figure 1A)

The bite force among hyperdivergent group was significantly less (p<0.05) when compared to Hypodivergent and Normodivergent individuals on the left (Figure 1B) and the right side. (Figure 1C)

There was no statistically significant difference between the right and the left side and also the gender difference was insignificant.

EMG analysis

At Maximum Voluntary Clenching

The EMG in hypodivergent group was significantly higher (p<0.01) when compared to normodivergent and hyperdivergent groups. The findings were statistically significant between normodivergent and hypodivergent (p-value=<0.01) and also hypodivergent and hyperdivergent groups (p-value=<0.01). The findings were statistically insigni-ficant between normodivergent and hyperdivergent groups (p-value=>0.05). (Figure 2A)

The EMG of hypodivergent group was significantly higher (p<0.01) when compared to normodivergent and hyperdivergent groups on the left (Figure 2B) and right side. (Figure 2C)

At Minimum Occlusion.

The EMG among of hypodivergent was significantly higher (p<0.05) when compared to normodivergent and hyperdivergent on the left (Figure 3A) and right side (Figure 3B).

The study showed strong correlation between bite force and masseter EMG activity. Divergence pattern and muscular activity has a proportional variation with the maximum bite force.

DISCUSSION.

The Muscular strength can be evaluated either by bite force or EMG recordings. Since bite force is strongly influenced by design and comfort of the transducer and the position of the transducer within the dental arch, the amount of voluntary effort, true muscle strength can be evaluated using EMG.

Since surface electrodes are non-invasive and helps to determine the masseter muscle activity of the larger surface area, it has been used in this study. The EMG activity of superficial masseter muscle can be influenced by factors like age, sex, facial morphology, connective tissue thickness, stress and pain.[8-11] As the analysis of bite force and the EMG activity of masseter muscle is a useful indicator of the functional state of the masticatory system and the loading patterns of the teeth, it was a parameter chosen for the study. In this study the correlation between the muscular activity and the functional efficiency with the craniofacial morphology are discussed.

In this study, the maximum bite force in hypodivergent group was more than normodivergent and hyperdivergent groups, which is in concordance to the findings of Ringqvist[12] and Profit *et al.*[13]

A negative co-relation was found between the bite force and divergence pattern, similar to the findings of Braun *et al.*,[1] who correlated bite force with facial morphology. Van Spronsen[14] suggested that the bite force in long face adults is attributed to the reduced size and reduced intrinsic strength of the masticatory muscles.

No difference in bite force between left and right side, in agreement with results of Bakke *et al.*[15]

The relationship between muscular activity and various facial divergence pattern have been studied.[16-19] Skeletal divergence patterns have also been related to muscle volume and thickness.[20] Theoretical models indicate a negative relationship between mechanical advantage and facial divergence pattern.[21] However, the relationship between facial divergence patterns and EMG masseter muscular activity remains controversial. which was in agreement with the present study.

The present study shows difference in the masseter muscle activity in various divergence pattern. The masseter muscular activity of Hypodivergent and Normodivergent facial pattern was higher when compared to hyperdivergence pattern. This is in agreement with the findings of Ueda *et al.,*[22] who found a relationship between the measurements of skeletal divergence and masticatory muscular activity (masseter, temporalis and digastric muscles), and no sex difference in the EMG muscular activity.

There is a strong correlation between the activity of masseter muscle and bite force. An increase in bite force results in increase in EMG activity; this demonstrates an increase of functional capacity of the masticatory muscle.[23]

Bite force may negate or complement the orthodontic vertical forces induced during treatment. Vertical stability is influenced by the muscle activity. Hence it is advantageous for the orthodontist to forecast the maximum bite force and masticatory muscle activity before starting the treatment.

Along with the skeletal factors the functional and neuromuscular factors must be considered to manage balance between craniofacial morphology and functional efficiency.

Limitations, the bite force sensor had to be reinforced with a putty material to intensify the reusability and this may have led to reduction in the recording of the bite force. The study could have included the EMG activity of other masticatory muscles such as temporalis muscle along with the masseter muscle activity for the comprehensive outcome of the masticatory system in various divergence patterns.

CONCLUSION.

Musculoskeletal build of an individual has a direct impact on the strength. The bite force of Hypodivergent jaw base individuals is highest followed by Normodivergent and least in Hyperdivergent individuals. Hypodivergence is usually seen as a characteristic feature in Brachycephalic and Euryprosopic type of cephalic/facial forms. The strong correlation between the muscular activity and the bite force is definitely a contributor to the anchorage value during treatment by fixed Orthodontics

Conflict of interests: The authors declare that they do not have any affiliation with any organization or entity, nor economic interests in the subject discussed in this manuscript.

Ethics approval: The study protocol and informed consent were evaluated and approved by the Ethics and Institutional review board of S.D.M. College of Dental Sciences and Hospital, Dharwad, India.

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