Comparative Evaluation of Occlusal Bite Force in Relation to the Muscle Activity in the Mixed Dentition Children of Age Group 9–12 Years: A T-scan Analysis

Tanuja Prabahar1, Nisha Gupta2, Nagalakshmi Chowdhary3, Nithin Kumar Sonnahalli4, Ramesh Chowdhary5, Vundela Rajashekar Reddy6

ABSTRACT

Aim and objective: Compare and evaluate the muscle activity and the occlusal force between the mixed dentition boys and girls of 9–12 years.

Materials and methods: The study included 15 boys and 15 girls. The occlusal force and activity of the masseter and temporalis muscle were measured with a T-scan device using a sensor, a module to transmit the signals to a computer and the complete data of the bite force and muscle activity with the EMG recordings and data were collected and evaluated.

Results: Relative occlusal force in the primary and permanent molars between the boys and girls showed no significant difference on the left side compared to the right. The electromyography values of masseter and temporalis in boys and girls showed a significant difference in which (TAR and MMR), (TAR and MML), (TAL and MMR), and (TAL and MML) are significant. The overall paired sample statistics showed higher muscle activity in masseter.

Conclusion: T-scan analysis has proved to be a dependable method for the evaluation of occlusal bite force with the muscle activity interpretation using EMG. This study concluded that there is a difference in the occlusal pattern and muscle activity in the mixed dentition that showed the maximum force was on the permanent molars and the symmetry of EMGs activity in children was on the right masseter comparatively with higher bite values in boys compared to girls.

Clinical significance: T-scan is a computerized analysis system that helps in the proper assessment of the patient’s occlusion and assists in the proper treatment planning and diagnosis accurately without much effort.

Keywords: EMG, Mixed dentition, Occlusal bite force, T-scan.

Introduction

The occlusal bite force is the key indicator for masticatory performance and it is defined as the forces exercised by the muscles of mastication in normal occlusion. These forces guide the function of the masticatory system resulting in the elevation of the muscles altered by the craniofacial biomechanics. It helps in coordinating the muscles, bones, and teeth of the masticatory system and is an important indicator of stomatognathic deformities.

The mixed dentition stage begins when the mandibular first permanent molars or incisors erupt. It is an interim period between both the dentition and continues till all the primary teeth are restored with the permanent. Studies have been reported that the growth and development period in any dentition includes environmental factors, nutrition, cultural variations, systemic variations, and individual differences.

The purpose of one’s bite force levels has been extensively used to follow the activity of the muscles. Measuring the masticatory force of individuals helps in understanding “the biomechanical principles of masticatory muscles”. Also, the masticatory force is important for the diagnosis and treatment of dysfunction. Studies showed higher muscular activity in masseter in males and temporals in females during clenching.

The contact between the teeth is referred to as occlusion. The indicators used for occlusion can be broadly divided as qualitative (articulating paper, articulating silk, articulating film, metallic shim stock film, high spot indicator) and quantitative (T-scan occlusal analysis system, virtual dental patient). There is no scientific correlation between the depth of the color and the mark using articulating paper and other qualitative methods because it cannot calculate the occlusal load. To resolve this in 1987 Maness et al. introduced a new computerized device (T-scan system; Sentek Crop, Boston, MA, USA) which precisely and dynamically records the time, force, and area of occlusal contacts and is used as a precise method for evaluating the occlusal pattern.

© The Author(s). 2021 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.
Comparative Evaluation of Occlusal Bite Force in Relation to the Muscle Activity in the Mixed Dentition Children

and simple clinical diagnostic device that detects the bite force using paper-thin disposable sensors.\(^9\) Later in 2006, two different dental technologies were bonded, i.e., T-scan II (Tekscan Inc., S. Boston, MA, USA) for windows and BioEMG II (Bioresearch, Inc., Milwaukee, WI, USA) for windows which synchronously recorded the electromyography levels and occlusal bite force.\(^10\)

Therefore, the recent advances to examine occlusal contacts and muscle function with computer technologies have paved way for the dentists. Studies have been done to compare the masticatory force and time using electromyography with T-scan in adults. Still, there remains a need to understand the occlusal bite force and muscle activity, in the mixed dentition age group. Hence, the current study was done to compare and evaluate the muscle activity in the mixed dentition age group of 9–12 years.

**Materials and Methods**

**Patient Selection**

The protocol of the study was accepted by the Institutional Ethical and Review Committee. A sum of 30 (15 boys and 15 girls) took part in the study with the age range of 9–12 years. The inclusion criteria included (1) Cooperative children, (2) Children with sound healthy dentition, (3) Children with no history of orthodontic treatment, (4) Children with no parafunctional habits, (5) Children with normal overjet and overbite, (6) Children with minor crowding or spacing, (7) Children with normal oral tissue, and (8) Children with permanent molars, whereas the exclusion criteria include (1) Children with TMJ disturbances, (2) Medically compromised children, (3) Children with apparent facial asymmetry that could affect the recordings, (4) Children with orthodontic treatment, (5) Children with anterior or posterior crossbites or open bite, and (6) Children with restorations. Thirty children who met the inclusion criteria were included in the study.

**Occlusal Bite Force**

To record the occlusal bite force, each child was made to sit comfortably with their head adjusted keeping the Frankfurt horizontal plane exactly parallel to the floor and body upright. All the participants of the study underwent surface electromyography (SEMG) recording with an 8-Channel BioEMG III BioPAK Measurement system Electromyograph (Bioresearch, Inc., Milwaukee, WI, USA) (Fig. 1). Before the recording, the area on the face where the EMG electrodes were to be placed was cleaned with spirit, EMG electrodes which are self-adhesive were placed in the masseter and temporalis area with the tip of each electrode aligned to the muscle fibers. In a single session, the measurements of the occlusal bite force were taken for each child, using a portable T-scan device. Before starting the test, each child was asked to prepare their best occlusal bite by biting onto the digital occlusal sensor (T-scan Novus). The digital occlusal scans were taken using a digital occlusal sensor and the data was thus recorded resulting in the distribution of occlusal force and this information was presented in 2D and 3D graphics by the Tekscan software. For each patient, a new single sensor sheet was used to obtain the scans (Fig. 2). The patient was instructed to bite with maximum biting force, making sure the teeth occluded normally and released. The sensor was inserted in such a way that the patient’s mouth was aligned centrally with the midline of the upper incisor and the patient was asked to bite with maximum intercuspation. This was repeated three times with an interval between each recording. The right value of the three occlusal bite forces was listed as the maximum occlusal bite force. The mean values were obtained and statistically analyzed.

**Results**

A total of 30 (15 boys and 15 girls) participated in the study with the age range of 9–12 years. Relative occlusal force and sEMG activity was calculated. This demonstrates the age and sex cross-tabulation of the mixed dentition age group which included 30 (15 boys and 15 girls) (Table 1). The statistical analysis was done using Mann–Whitney test which compared the relative occlusal force of the anterior and posterior right and left region of the jaw and found that no significant difference was seen between boys and girls. The data were expressed as mean ± SD (Table 2). Comparison of the mean and standard deviation of the relative occlusal force in the

---

**Fig. 1:** Participant of the T-scan study with BioEMG III BioPAK Measurement system connected with EMG electrodes

**Fig. 2:** Participants occlusal bite force and EMG recordings
primary and permanent molars between boys and girls. The mean value was seen to be higher on the left permanent molar compared to the right molar in girls (Table 3). Surface EMG recording from the left temporalis anterior (TAL), right temporalis anterior (TAR), and left masseter muscle (MML) and right masseter muscle (MMR) demonstrated a statistically significant difference in the voltage of the muscles, whereas no significant difference was seen in the right masseter muscle (MMR) ($p = 0.146$). According to gender, the sEMG value showed a significant difference in boys and girls (Table 4). Paired sample statistics with a mean and standard deviation of the relative occlusal force on AL, AR, PL, and PR (boys and girls) was done using Wilcoxon signed-rank test (Table 5). The paired sample statistics showed a significant difference in the relative occlusal force in anterior left and posterior right respectively (Table 6). Paired sample statistics of EMG boys and girls showed a significant difference in Pair 2 (TAR and MMR), Pair 3 (TAR and MML), Pair 4 (TAL and MMR), and Pair 5 (TAL and MML). The overall paired sample statistics showed higher muscle activity in masseter (Table 7).

A positive comparison was seen between muscle activity and occlusal force in both boys and girls of the mixed dentition age group (Table 8).

### Discussion

Occlusal bite force indicates the state of functional mastication and loading of teeth which often leads to jaw elevations with the help of muscles that are determined by the central nervous system and are retrogressed from the muscle spindles, mechanoreceptors, and nociceptors which leads to alteration of craniomandibular biomechanics. It is generally said that a superior masticatory system leads to a stronger bite force. Studies proposed by Rentes et al.; Kamegai et al.; Sonnesen and Bakke have shown that the

| Table 1: Age and sex cross-tabulation of the mixed dentition age group |
|---|
| **Age** | **Boys** | **Girls** | **Total** |
| 9 | 3 | 3 | 6 |
| 10 | 6 | 5 | 11 |
| 11 | 2 | 5 | 7 |
| 12 | 4 | 2 | 6 |
| **Total** | **Total** | **15** | **15** | **30** |

$p value < 0.05$, Statistically significant

| Table 2: Comparison of the mean and standard deviation for the relative occlusal force between the male and female using Mann–Whitney test |
|---|
| **Sex** | **N** | **Mean** | **Std. deviation** | **Mean rank** | **Mean difference** | **Mann–Whitney U** | **p value** |
| Relative occlusal force–AL | Boys | 15 | 7.57 | 10.63 | 17.17 | $-1.763$ | 87.500 | 0.299 |
| | Girls | 15 | 9.34 | 13.73 | 13.83 | | |
| Relative occlusal force–AR | Boys | 15 | 11.14 | 9.32 | 16.60 | $-0.028$ | 96.000 | 0.492 |
| | Girls | 15 | 11.17 | 13.52 | 14.40 | | |
| Relative occlusal force–PL | Boys | 15 | 37.14 | 14.76 | 13.83 | $-4.875$ | 87.500 | 0.300 |
| | Girls | 15 | 42.02 | 20.03 | 17.17 | | |
| Relative occlusal force–PR | Boys | 15 | 43.74 | 18.78 | 17.10 | $7.973$ | 88.500 | 0.319 |
| | Girls | 15 | 35.77 | 20.01 | 13.90 | | |

| Table 3: Comparison of the mean and standard deviation of the relative occlusal force in the primary and permanent molars between boys and girls using Mann–Whitney test |
|---|
| **Sex** | **N** | **Mean** | **Std. deviation** | **Mean rank** | **Mean difference** | **Mann–Whitney U** | **p value** |
| Relative occlusal force–T55,85 | Boys | 13 | 4.88 | 5.81 | 11.04 | $-7.530$ | 52.500 | 0.060 |
| | Girls | 14 | 12.41 | 9.83 | 16.75 | | |
| Relative occlusal force–T16,46 | Boys | 15 | 26.83 | 13.08 | 18.03 | $8.093$ | 74.500 | 0.115 |
| | Girls | 15 | 18.74 | 13.13 | 12.97 | | |
| Relative occlusal force–T65,75 | Boys | 15 | 13.76 | 10.56 | 14.70 | $-2.180$ | 100.000 | 0.618 |
| | Girls | 15 | 15.94 | 14.00 | 16.30 | | |
| Relative occlusal force–T26,36 | Boys | 15 | 13.47 | 15.34 | 12.33 | $-13.873$ | 65.000 | 0.048 |
| | Girls | 15 | 27.34 | 17.26 | 18.67 | | |

| Table 4: EMG values for right and left masseter and temporalis in boys and girls using Mann–Whitney test |
|---|
| **Sex** | **N** | **Mean** | **Std. deviation** | **Mean rank** | **Mean difference** | **Mann–Whitney U** | **p value** |
| Electromyography–TAR | Boys | 15 | 109.52 | 44.86 | 18.77 | 34.029 | 63.500 | 0.042 |
| | Girls | 15 | 75.49 | 45.70 | 12.23 | | |
| Electromyography–TAL | Boys | 15 | 131.52 | 41.90 | 19.33 | 47.387 | 55.000 | 0.017 |
| | Girls | 15 | 84.13 | 51.11 | 11.67 | | |
| Electromyography–MMR | Boys | 15 | 187.46 | 80.62 | 17.83 | 45.696 | 77.500 | 0.146 |
| | Girls | 15 | 141.76 | 63.47 | 13.17 | | |
| Electromyography–MML | Boys | 15 | 238.03 | 98.97 | 20.00 | 94.855 | 45.000 | 0.005 |
| | Girls | 15 | 143.17 | 59.69 | 11.00 | | |
individuals’ bite force levels have been broadly used to understand the mastication mechanisms and the effects of their therapies. This study aimed to check if there was any correlation between the muscle activity and occlusal bite force distribution in asymptomatic young children of age group 9–12 years. A thorough search was done on studies related to the distribution of forces and the relationship between the occlusal contact and the EMG of the masseter and temporalis muscle. Therefore, studies involving the

| Pair  | Relative occlusal force–AL  | N  | Mean   | Std. deviation | Mean difference | Z    | p value |
|-------|-----------------------------|----|--------|---------------|----------------|------|---------|
| 1     | Relative occlusal force–AR  | 30 | 8.45   | 12.10         | −2.699         | −1.389| 0.165   |
|       | Relative occlusal force–PL  | 30 | 39.58  | 17.47         | −31.123        | −3.960| 0.000   |
| 2     | Relative occlusal force–PR  | 30 | 39.75  | 19.49         | −0.176         | −0.195| 0.845   |

| Table 6: Paired T sample test correlation of the relative occlusal force in (boys and girls) |
|-------|---------------------------------|----|--------|----------------|----------------|------|---------|
| Pair  | Relative occlusal force–AL and Relative occlusal force–AR | 30 | 0.784 | 0.000 |
|       | Relative occlusal force–AL and Relative occlusal force–PL | 30 | −0.433 | 0.017 |
|       | Relative occlusal force AR and Relative occlusal force–PR | 30 | −0.492 | 0.006 |
|       | Relative occlusal force–PL and Relative occlusal force–PR | 30 | −0.327 | 0.077 |

| Table 7: Paired sample statistics of EMG (girls and boys) |
|-------|---------------------------------|----|--------|----------------|----------------|------|---------|
| Pair  | Electromyography–TAR            | 30 | 92.50  | 47.74         | −15.320        | −2.911| 0.004   |
|       | Electromyography–TAL            | 30 | 107.82 | 51.86         | −9.212         | −1.65 | 0.102   |
|       | Electromyography–MMR            | 30 | 164.61 | 74.98         | −98.100        | −4.700| 0.000   |
|       | Electromyography–MML            | 30 | 190.60 | 93.68         | −25.992        | −2.643| 0.008   |

| Table 8: Paired sample statistics of EMG (girls and boys) |
|-------|---------------------------------|----|--------|----------------|----------------|------|---------|
| Pair  | Electromyography–TAR            | 30 | 92.50  | 47.74         | −15.320        | −2.911| 0.004   |
|       | Electromyography–TAL            | 30 | 107.82 | 51.86         | −9.212         | −1.65 | 0.102   |
|       | Electromyography–MMR            | 30 | 164.61 | 74.98         | −98.100        | −4.700| 0.000   |
|       | Electromyography–MML            | 30 | 190.60 | 93.68         | −25.992        | −2.643| 0.008   |
mixed dentition age group are limited in the literature. During the mixed dentition age group, all the lower 1st permanent molars, incisors erupt and deciduous molars are still present or maybe on the verge of exfoliation.

Many studies show that there is a significant relationship between maximum occlusal bite force and the stage of dentition. This relation could be compared to the development of the stomatognatic system and masticatory muscle efficiency in different stages of dentition. The relation was significantly noticed by the transition stage of early mixed to late mixed dentition stage. Sonnesen et al. who has done a similar study reported a significant relationship between the maximum occlusal bite force and the increasing stage of dental eruption in children aged 7–13 years. Fontijn-Tekamp et al. suggested that masticatory performance improvised as the number of occlusal proximity increases.

The bite forces may differ within the location of the oral cavity and force was maximum in the first molar region.

The occlusal tooth contact is maximum in the posterior region due to the biomechanics of the jaw elevators muscles and the lever system of the mandible and is more in the molar region than on the incisors. At the age of 9 years, the age and gender are related to the force and they begin to increase at when the formation of the root of the first molar is complete. The average increase in the rate of bite force on the permanent molars in children.

Our study was based on, asymptomatic young children where the maximum bite force was seen more posteriorly and on the left side region. It has also shown that the boys have maximum bite force compared to girls and the change in growth intensity between the male and female is the main reason for the difference in bite force in permanent dentition. The correlation of bite force to gender is not evident till the age of 18 years because of the excretion of ketosteroids in postpubertal young males which is related to an increase of muscle mass. This increase in muscle mass occurs at a greater rate in males only beyond 16 years when compared to that of females.

The present study also revealed that the voltage in healthy asymptomatic children which showed a significant result in masseter region in male than in the female.

Ferrario et al. in 2010 have done a similar study and has found out that the prevalence of the temporals anterior in the female, while in the male there was a prevalence of masseter muscle which was also similar to our study in which the right masseter shows maximum muscle activity in boys compared to girls.

Some other studies reported that the superficial masseter muscles EMG activity is significantly influenced by the T-scan sensor, whereas it does not affect the anterior temporals in comparison to occlusion with the natural dentition. No studies were found on jaw muscle activity neither in normal occlusive children nor in children with unilateral crossbite within the early mixed dentition stage comparing differences between sexes. In normal young adults, some studies also found sexual differences with higher EMG activity in masseter or higher activities in masseter and anterior temporals. Shino gaya et al. in 1999 reported that the total bite force was 80% is distributed within the molar area. Therefore, within the present investigation, MVBF was measured within the first permanent molar region, and therefore the subjects were selected consistent with strict inclusion criteria.

In this study, children of 9–12 years participated in the study. During this mixed dentition phase, the root resorption physiology of primary molars begins. Hence, the root of the molars may not have formed resulting in lower bite force. In our study, all the first molars erupt which carries the maximum occlusal bite force. However, different factors might be attributed to the observed differences in the bite force magnitude, including various supporting structures of the teeth along with the child’s tooth, changes in the maximum voluntary activity of the masticatory muscles within different regions of the dental arch, and the need to maintain joint stability during dynamic force production.

The findings procured from this study are important since they helped in determining absolute bite force and muscle activity in healthy young children aged 9–12 years. Thus, the data can therefore serve to provide a further reference for use in both pediatric dental and clinical practice and for further wider researches.

**Conclusion**

The T-scan Novus system has proved to be the most efficient method for the analysis and evaluation of occlusal bite force with the muscle activity interpretation using EMG. Though its cost is very high, it can be a reliable method for clinical evaluation and understanding of occlusal difficulties which are faced in day-to-day practice. It is definitely a valuable diagnostic tool that has high sensitivity and specificity. Therefore, this study concluded that there is a difference in the occlusal bite force and muscle activity in the mixed dentition which also concluded that the maximum force was on the permanent molars and the symmetry of EMGs activity in children was seen on the left masseter with higher bite values in male compared to female.

**Acknowledgments**

Ethical clearance for the study was received from the Institutional Ethical Committee, Sri Siddhartha Medical College, Tumakuru. The authors wish to thank all the participants for their cooperation and extend their gratitude to the Branemark osseointegration center, Vijayanagar, Bengaluru for the guide and support with the T-scan device and sensors. The authors do not have any financial interests in Tekscan and there is no conflict of interests.

**References**

1. Subramaniam P, Girish Babu KL, Ifzah. Evaluation of occlusal forces in different stages of children – an exploratory study. Saudi J Oral Sci 2018;5:11–16.
2. Owais AL, Shaweesh M, Abu Alhaija ES. Maximum occlusal bite force for children in different dentition stages. Eur J Orthod 2013;35(4):427–433.
3. Calderon Pdos S, Kogawa EM, Lauris JR, et al. The influence of gender and bruxism on the human maximum bite force. J Appl Oral Sci 2006;14(6):448–453.
4. Louly F, Nauer PR, Janson G, et al. Dental arch dimensions in the mixed dentition: a study of Brazilian children from 9 to 12 years of age. J Appl Oral Sci 2011;19(2):169–174.
5. Mountain G, Wood D, Toumba J. Bite force measurement in children with primary dentition. Int J Paediatr Dent 2011;21(2):112–118.
6. Amid R, Ebrahimni M, Kadhodazadeh M, et al. New device to measurement of maximum bite force. Dentist Case Rep 2018;2(2):26–29.
7. Wieczorek A, Loster JE. Activity of the masticatory muscles and occlusal contacts in young adults with and without orthodontic treatment. BMC Oral Health 2015;15(1):116.
8. Ferrario VF, Sforza C, Miani A Jr, et al. Electromyographic activity of human masticatory muscles in normal young people. Statistical evaluation of reference values for clinical applications. J Oral Rehabil 1993;20(3):271–280.
9. Pyakurel U, Long H, Jian F. Mechanism, accuracy and application of T-Scan system in dentistry – a review. JNDA 2013;13.
10. Kerstein RB, Radke J. Masseter and temporalis excursive hyperactivity decreased by measured anterior guidance development. Cranio. 2012;30(4):243–254.
11. Castelo PM, Pereira LJ, Bonjardim LR, et al. Changes in bite force, masticatory muscle thickness, and facial morphology between primary and mixed dentition in preschool children with normal occlusion. Ann Anatomy 2010;192:23–26.
12. Sonnesen L, Bakke M, Solow B. Temporomandibular disorders in relation to craniofacial dimensions, head posture and and bite force in children selected for orthodontics treatment. Eur J Orthodont 2001;23:179–192.
13. Fontijn-Tekamp F, Slagter AP, Van Der Bilt A, et al. Biting and chewing in overdenture, full dentures and natural dentitions. J Dent Res 2001;79:1519–1524.
14. Bakke M. Bite force and occlusion. Semi Orthodont 2006;12:120–126.
15. Sonnesen L, Bakke M. Molar bite force in relation to occlusion, craniofacial dimensions and head posture in pre-orthodontic children. Eur J Orthodont 2005;27:58–63.
16. Braun S, Hnat WP, Freudenthaler JW, et al. A study of maximum bite force during growth and development. Angle Orthodont 1996;66:261–264.
17. Ferrario V, Sforza C, Zanotti G, et al. Maximal bite force in healthy young adults as predicted by surface electromyography. J Dent 2004;32:451–457.
18. Lenguas L, Alacarcon JA, Venancio F, et al. Surface electromyographic evaluation of jaw muscles in children with unilateral cross bite and lateral shift in early mixed dentition. Sexual dimorphism. Med Oral Patol Oral Cirbucal 2012;17(6):e1096–e1102.
19. Varga S, Spalj S, Varga ML, et al. Maximum voluntary molar bite force in subjects with normal occlusion. Eur J Orthodont 2011;33(4):427–433.