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Research Article

A QUANTITATIVE ASSESSMENT OF STRUCTURAL IMBALANCE AND FUNCTIONAL IMPAIRMENT CAUSED DURING FIXED ORTHODONTIC TREATMENT IN HYPERDIVERGENT INDIVIDUALS - A PROSPECTIVE STUDY

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A B S T R A C T

Introduction: Stable functional occlusion is an important criteria during orthodontic treatment. A more descriptive and detailed evaluation of interarchocclusal contacts in association with trabecular changes of the bone is not done routinely in orthodontics.

Materials and methods: 120 hyperdivergent male subjects, age ranging from 16-25 years were evaluated using T-Scan III system along with associated software to record force distribution in dental arch. Force distribution was assessed in the following intervals C_0-1st day and C_1-120days in 60 control group (CG) subjects, E_0-1st day, E_1-7days, E_2-30days, E_3-60days, E_4- 120days in 60 experimental group (EG) subjects. The OPG and IOPAR of molar-premolar region were taken for all the subjects to assess the trabeculae changes of the bone during orthodontic treatment. The data obtained was statistically analysed using independent and paired t test.

Results: Comparison of force distribution C_0-1st day, C_1-120days and E_0-1st day, E_4-120days in control and experimental groups of right and left side showed insignificant changes ($p>0.05$). The force distribution on the right and left sides at different time period showed significant difference only after 60days of fixed mechanotherapy.There was significant change in number of vertical and horizontal bone trabeculae and angulation of horizontal bone trabeculae between E_0 -1st day and E_4 -120 days in the right and left sides ($p<0.05$).

Conclusions: Clinically there was a significant increase in force distribution, only after 60 days of fixed mechanotherapy in hyper divergent individuals attributing to functional occlusal changes. The change in the number of horizontal trabeculae and their angulations show the amount of structural imbalance occurring during the initial stages of fixed orthodontic treatment.

INTRODUCTION

The primary goal of orthodontic treatment is to correct dental malocclusion and correction of various craniofacial deformities providing better esthetics to patient. The treatment should improve dental esthetics, facial esthetics, functional occlusion and stability. But often unstable functional occlusion is achieved leading to imbalance in the stomatognathic system. Maximum bite force has an influence on the masticatory muscle activity and the function of the masticatory system.[1-3]The variation in the maximum bite force value can be attributed to several factors such as physical characteristics and craniofacial morphology or could be technique related.

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Various studies have shown the effect of muscle activity on the growth pattern of the jaws, while hypodivergent growth pattern has been associated with strong musculature, hyperdivergent individuals usually have weak and flaccid muscles.[4] Stable functional occlusion is an important criteria during orthodontic treatment, a more descriptive and detailed evaluation of interarchocclusal contacts is not been done routinely in orthodontics. It would be interesting to record occlusal changes within one month of arch wire placement and follow up evaluation of occlusal changes by using recent advanced techniques.

A numerous quantitative and qualitative methods of occlusal analysis are used presently: inked marking strips, waxes, silicones and photo occlusion, which is the only qualitative assessment procedure.[5] One of the most advanced systems for quantitative occlusal analysis is T-Scan, which is considered as a computerized device capable of interpreting occlusal contact

information quantitatively, through a menu driven software. The T-Scan system uses a sensor unit that records occlusal contacts on a thin Mylar film and relays the information to the computer. The device enables the dentist to interpret occlusal contact information quantitatively, using time as the primary diagnostic variable.[6]

Objectives of the Study

The aim of this study is to assess the changes in relative bite force distribution during fixed orthodontic treatment, in hyperdivergent male during the initial stages of fixed Orthodontic treatment.

MATERIALS AND METHODS

This was a prospective clinical study of 120 subjects age ranging from 16-25 years. A post hoc power analysis for this sample size revealed an effect size of 0.35 and a statistical power of 0.6 for the study. Before proceeding with the study, the protocol was reviewed and clearance from Ethical committee of institution was obtained. A signed informed consent from the adult subjects, and guardians of the minor participants was obtained. The inclusion and exclusion criteria were as follows.

Inclusion Criteria

1. Skeletal Class I hyperdivergent growth patterns.
2. SN to Go-Gn [Steiner's analysis][7]
i. $>35^0$ for hyperdivergent patients
3. Straight or mild convex/concave profile (Non-surgical cases ANB range2^0 to 5^0) [Steiner's analysis][7]
4. Full complement of teeth from central incisor to second molar in all the four quadrants.
5. Age group 16-25 years.

Exclusion Criteria

1. Severe skeletal Class II and Class III patients with Hypodivergent and Normodivergent growth pattern
2. Missing teeth, Prosthesis, Implants. Decayed and teeth without restorations.
3. Any TMJ or muscular abnormalities as reported by patients or identified on clinical examinations.

Materials used in the study

Pre-treatment records in the form of photographs, impressions and radiographs (Lateral Cephalogram, OPG) were taken for all the subjects. The divergence pattern was assessed based on the following cephalometric values:

	SN-GoGn
Hyperdivergent	$>35^0$

Collection of data

1. Lateral cephalogram were taken for each patient and the divergence pattern were assessed according to the SN-Go, Gn angle.
2. Relative force distribution and occlusal contacts were recorded using T-Scan III system and sensor.
3. Intra oral periapical radiograph (IOPAR) were taken in molar premolar region and Orthopantomograph (OPG) to assess the trabeculae pattern change and inclination of trabeculae.

The Control group (CG) was assessed 2 times.

1. $\mathbf{C_0}$– 1st day/ Pre-treatment
2. (Lateral cephalogram, IOPAR, OPG, Force distribution with T-Scan III system)
3. $\mathbf{C_1}$- 120 days.
4. (IOPAR, OPG, Force distribution with T-Scan III system)

The Experimental group (EG) was assessed 5 times at the following intervals

1. $\mathbf{E_0}$- Pre-treatment.
2. (Lateral cephalograms, IOPAR, OPG, and Force distribution with T-Scan III system)
3. $\mathbf{E_1}$- 7 days after first arch wire placement.
4. (Force distribution with T-Scan III system)
5. $\mathbf{E_2}$- 30 days after first arch wire placement.
6. (Force distribution with T-Scan III system)
7. $\mathbf{E_3}$- 60 days after first arch wire placement.
8. (Force distribution with T-Scan III system)
9. $\mathbf{E_4}$- 120 days after first arch wire placement.
10. (IOPAR, OPG, Force distribution with T-Scan III system)

Force distribution recording

Force distribution was recorded using the T-Scan III computerized occlusal analysis system (Software Version 8.0, Tekscan Inc. South Boston, MA, USA) uses an electronically-charged, mylar-encased recording sensor (High-definition Generation IV sensor, Tekscan Inc. S. Boston, MA, USA) (fig1).[6, 8] The recording sensor is placed intraorally between the dental arches to capture real-time occlusal force and time-sequence data when a subject intercuspates or makes excursive movements across its recording surface. The software processes the occlusal data of any recorded occlusal event for graphical display in 2 and 3 dimensions.

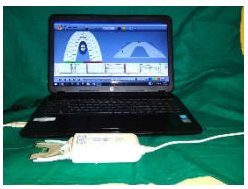

Fig 1 T-Scan III system (Tekscan) and associated software

The patient was asked to sit upright on the dental chair such that the Frankfort horizontal plane was approximately parallel to the floor and remained steady while biting on the sensor (fig2). Subjects were previously trained to close in maximum intercuspation. The sensor was inserted into the patient's mouth to make its support aligned centrally with the midline of the upper incisors. The patient was then asked to bite on the sensor in maximum intercuspation. Three sets of readings were recorded with a gap of 1 minutes to rule out intra-operator errors. To exclude inter-examiner errors, all recordings were performed by the same examiner.

Fig 2 T-Scan recording on patient

Assessment of trabecular pattern change

The alveolar bone surrounding the maxillary and mandibular molar, premolar region was assessed using digitized IOPAR and OPG.[9, 10] The Region of interest in assessing the bone trabeculae is interdental surface of 1st molar and 2nd premolar region.. Then the IOPAs were enlarged by 4 times and print was taken in grayscale. The printed grayscale radiographs were taken and long axis of 1st molar was marked by line joining mesial cusp tip and mesial root apex. Number of vertical and horizontal trabeculae were counted and the angulation of horizontal trabeculaes were calculated by taking long axis of the 1st molar as the reference. The average angulation of all the trabeculae were taken into consideration. The number of trabeculae during the pretreatment (E_0) and after 120days (E_4) were compared to check the trabeculae changes. (fig 3 & 4)

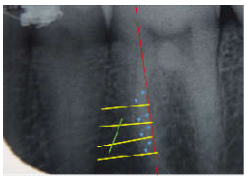

Fig 3 Digitized IOPA showing Horizontal (Yellow) trabeculae and its angulation and Vertical (Green) trabeculae at E_0 (1st day)

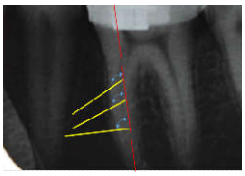

Fig 4 Digitized IOPA showing Horizontal (Yellow) trabeculae and its angulation at E_4 (120 days)

Statistical Analysis

Statistical analyses were performed using PASW 21 version, USA. The significance value was established at $p<0.05$.Independent t test was employed to find the difference in the mean bite force distribution between the two groups. Paired t-test was employed to find the difference in the mean bite force within the group, Repeated measures ANOVA followed by Post hoc Bonferoni test was employed to find out the difference in the bite force at different time intervals.

RESULTS

Comparison of relative biteforce distribution of control and experimental groups of right and left side C_0-1st day, C_1-120days and E_0-1st day, E_4- 120 days by independent t test. The findings show that there is statistically significant difference in force distribution of CG and EG group between 1st day ($p<0.05$). Whereas after 120 days there is no significant change in force distribution among CG and EG group but there is change in force distribution clinically ($p>0.05$) (Table 1)

Table 1 Comparison of biteforce distribution among control group CG and experimental EG group (C_0-1st day, and E_0-1st day, E_4-120days) by Independent sample t test.

		Group	Mean in %	Std. Deviation	Std. Error mean	T statistic	P value
RIGHT SIDE	C_0-1st day	CG	51.88	8.87	1.14	2.948	0.004
	E_0-1st day	EG	45.86	13.11	1.69		
	C_1-120days	CG	51.540	6.6220	0.8549	-1.820	0.072
	E_4-120days	EG	48.363	11.7913	1.5222		
LEFT SIDE	C_0-1st day	CG	48.14	8.84	1.14	-2.935	0.004
	E_0-1st day	EG	54.14	13.11	1.69		
	C_1-120days	CG	48.427	6.5930	0.8512	1.841	0.069
	E_4-120days	EG	51.637	11.7913	1.5222		

Table 2 Table showing change in the biteforce distribution from E_0-1st day to E_4- 120days in experimental group by Repeated measure ANOVA.

	Mean in %	Std. Deviation	F value	P value
Force disribution right side e_0-1st day	45.86	13.111		
Force disribution right side e_1-7days	45.86	11.704		
Force disribution right side e_2-30days	45.24	10.244	4.133	**0.005**
Force disribution right side e_3-60days	46.09	10.82		
Force disribution right side e_4- 120days	48.36	11.79		
Force disribution left side e_0-1st day	54.14	13.11		
Force disribution left side e_1-7days	54.14	11.70		
Force disribution left side e_2-30days	54.75	10.24	4.133	**0.005**
Force disribution left side e_3-60days	53.90	10.82		
Force disribution left side e_4- 120days	51.63	11.79		

Repeated measure ANOVA used to find change in bite force distribution among experimental group between E_0-1st day to E_4- 120days showed statistically significant difference at different time intervals ($p<0.05$) (Table 2) It was followed by post hoc Bonferroni test for pairwise comparison of change in relative biteforce distribution on the right and left sides at different time points which showed there is significant difference between force distribution of right side at E_0 -1st day and E_4 -120 days, E_1 -7 days and E_4 -120 days, E_2 -30 days and E_4 -120 days, E_3 -60 days and E_4 -120 days ($p<0.01$). Also between the force distribution of left side at E_0 -1st days and E_4 -120 days, E_1 -7 days and E_4 -120 days, E_2 -30 days and E_4 -120 days, E_3 -60 days and E_4 -120 days ($p<0.05$). By this it elucidated that the force distribution change is seen only after 60days of fixed orthodontic treatment if we consider the time intervals of force distribution measurement. (Table 3)

Correlating the change in relative biteforce distribution and change in number of vertical and horizontal bone trabeculae between E_0 -1st day and E_4 -120 days in the right and left sides of group was done by Spearmans correlation coefficient test which showed significant moderate positive correlation (0.427) between force distribution of left side and horizontal trabeculae angulation on the left side. Significant weak negative correlation (-0.247) between bite force distribution of right side and vertical trabecuae of right side. Significant weak positive correlation (0.299) between force distribution of right side and horizontal trabeculae bone angulation on the right side ($p<0.05$). (Table 4)

The change in the number of horizontal trabeculae and their angulations show the amount of bone destruction occurring during the initial stages of fixed orthodontic treatment which attributes to bone remodelling process leading to a change in force distribution.

DISCUSSION

A common assumption made by the patient undergoing orthodontic treatment is that they have inadequate biting power, where patient is not able to exert excessive occlusal force. There is a myth that the orthodontic treatment will lead to loss of masticatory efficiency. Changes in occlusion arising during initial levelling alignment phase leads to problems in mastication which have not been documented quantitatively till date.

Table 3 Pairwise comparison of the change in biteforce distribution at different time intervals from E_0-1st day to E_4-120days in experimental group

	Time	Time	Mean difference	Std. Error	P value
RIGHT SIDE	E_0-1st day	E_1-7days	0.003	0.688	1.000
		E_2-30days	0.618	1.021	1.000
		E_3-60days	-0.238	1.056	1.000
		E_4- 120days	-2.503*	0.845	**0.044**
	E_1-7days	E_2-30days	0.615	0.837	1.000
		E_3-60days	-0.242	0.880	1.000
		E_4- 120days	-2.507*	0.780	**0.021**
	E_2-30days	E_3-60days	-0.857	0.914	1.000
		E_4- 120days	-3.122*	0.965	**0.020**
	E_3-60days	E_4- 120days	-2.265*	0.759	**0.041**
LEFT SIDE	E_0-1st day	E_1-7days	-0.003	0.688	1.000
		E_2-30days	-0.618	1.021	1.000
		E_3-60days	0.238	1.056	1.000
		E_4- 120days	2.503*	0.845	**0.044**
	E_1-7days	E_2-30days	-0.615	0.837	1.000
		E_3-60days	0.242	0.880	1.000
		E_4- 120days	2.507*	0.780	**0.021**
	E_2-30days	E_3-60days	0.857	0.914	1.000
		E_4- 120days	3.122*	0.965	**0.020**
	E_3-60days	E_4- 120days	2.265*	0.759	**0.041**

In this study the force distribution is measured using T-Scan III system and T- Scan sensor which gives a quantitative reading of relative force distribution of right and left side, which can be used to compare the force distribution. The bone trabeculae changes gives idea of functional changes in trabeculae which occur during fixed orthodontics treatment.[10] The present literature supporting the conventional occlusion analysis need advanced system which provides information of static as well as dynamic occlusal contacts.

Table 4 Spearmans correlation showing correlation between change in biteforce distribution, trabeculae pattern and angulation after 120 days

		Verticle bone trabeculae left side	Horizontal bone trabeculae left side	Horizontal angulation left side
Force distribution leftside	Correlation Coefficient r VALUE	0.159	-0.120	0.427
	p VALUE	0.226	0.361	**0.001**
	N	60	60	60
		Verticle bone trabeculae right side	Horizontal bone trabeculae right side	Horizontal angulation right side
Force distribution rightside	Correlation Coefficient r VALUE	-0.247	-0.099	0.299
	p VALUE	**0.057**	0.452	0.**020**
	N	60	60	60

The conventional static occlusal indicators such as articulating paper and waxes only reveal the contact size and location, whereas the T-Scan has an additional ability of quantifying occlusal contact timings and forces also it is very sensitive to minor change in occlusion.[11,12] The biteforce is a useful indicator of the functional state of the masticatory system and the loading pattern of the teeth. The muscular strength can be evaluated by biteforce or EMG recordings. In the present study data recorded is taken as right and left force distribution which is correlated with the trabeculae bone changes in the IOPAR and OPG.

The functional disturbance in mastication is depicted by change in trabeculae of bone.[13,14] Sultana, Yamada, Hanada, studied the change in occlusal force and occlusal contact area after active orthodontic treatment using a pressure sensitive sheet, which concluded that the number of occlusal contacts improved gradually during retention phase.[15] Freitas *et al*.[16] studied posttreatment and physiological occlusal changes caused by natural development, the study concluded that the post treatment change of the mandibular anterior crowding of the treated extraction group was greater than the mandibular crowding caused by physiologic changes in the untreated group. The structural adaptation of the mandibular bone when subjected to different masticatory functional and mechanical demands during growth were studied and it was found that masticatory loading alters and changes the bone density and trabeculae.[17, 18]

In this study, a control group was used to record occlusal force distribution changes in subjects with normal occlusion.

When the biteforce distribution among control group and experimental group (C_0-1st day, C_1-120days and E_0-1st day, E_4-120 days) was compared, though there was no statistical significant changes in occlusal force distribution values over 120 days, there was change in force distribution clinically to small extent which can be attributed to physiological changes. Which is supported by study done by Alomari and Abu Alhaija.[19]

Malocclusion are associated with reduced occlusal force.[20] The change in bite force distribution among experimental group between E_0-1st day to E_4- 120 days subjects showed significant increase in force distribution only after 60 days of fixed orthodontic treatment.In the present study only class I malocclusion subjects were taken which is believed to have

lesser problem in mastication. The relative force distribution of right and left side is recorded, which shows that higher occlusal force in preferred chewing side which could be associated with expressing of the higher muscular force on that side. Bicaj *et al*.[21] studied the relation between the preferred chewing side and occlusal force measured by T-Scan III system. Occlusal force was higher in the preferred chewing side. There was no statistical significance of occlusal force according to the quadrants: anterior left, anterior right, posterior left and posterior right. In the present study also there is no statistical significance of occlusal force according to the right and left region but there is a difference in the force distribution. The more detailed study is required to correlate the right and left force distribution variation and muscle activity in right and left side.

Trabecular bone alignment and orientation are adaptive to changes in the mechanical environment, such as those induced by aging or osteoporosis. In these conditions some trabeculae disappear, trabeculae oriented in the direction of the main forces applied to the bone, or they might change their orientation because of the adaptation phenomenon.[22, 23] In this study number of horizontal and vertical trabeculae and orientation of horizontal trabeculae changes were assessed, change in number of vertical trabeculae was not appreciated much where as the number of horizontal trabeculae on right and left side changed and angulation of horizontal trabeculae also changed between the E_0 -1st day and E_4 -120 days during fixed mechanotherapy which is supported by study done by Ahmad *et al*.[24] These findings shows that there is functional changes in the bone trabeculae which is directly proportional changes to the force distribution. The significant change in force distribution is elucidated only after 60days of fixed orthodontic treatment which can be correlated with change in number of horizontal and vertical trabeculae and the angulation of horizontal tabeculae. The force distribution change is directly proportional to the change in number and angulation of trabecular bone which elucidates the bone remodelling process occurring during the fixed orthodontic treatment.

CONCLUSION

- There was a significant increase in force distribution clinically, only after 60 days of fixed orthodontic treatment in Hyperdivergent individuals.
- The bilateral variation of the relative force distribution is insignificant. Entire study did not show any changes in force distribution of the right and left side at any period.
- The change in the number of horizontal trabeculae and their angulations show the amount of structural imbalance occurring during the initial stages of fixed orthodontic treatment which attributes to bone remodelling process leading to a change in force distribution elucidating that the trabecular pattern definitely change in 60 days of fixed orthodontic treatment.

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