International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: SJIF: 5.995
Available Online at www.journalijcar.org
Volume 6; Issue 12; December 2017; Page No. 7976-7981
DOI: http://dx.doi.org/10.24327/ijcar.2017.7981.1265

Research Article

CLINICAL EVALUATION OF CENTER OF RESISTANCE OF MAXILLARY ANTERIOR TEETH DURING EN MASSE RETRACTION WITH MINI IMPLANT ANCHORAGE

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A R T I C L E I N F O

Article History:
Received 9th September, 2017
Received in revised form 12th October, 2017
Accepted 23rd November, 2017
Published online 28th December, 2017

Key words:
Center of resistance, mini- implants, power arm length, retraction, translation,

A B S T R A C T

Objectives: To clinically evaluate the center of resistance of maxillary anterior teeth and check the validity and applicability of power arm of proposed length for bodily translation of maxillary anterior teeth during en masse retraction using mini-implants as anchorage.
Materials and Methods:: Thirty patients with Angles Class I or Class II malocclusion, who were undergoing standard preadjusted edgewise technique (MBT prescription, 3M Unitek), including extraction of maxillary first premolars were selected and retraction forces were applied through power arm of length 5 mm soldered to the arch wire between lateral incisor and canine with mini implants placed between maxillary first molar and second premolar as anchorage, assuming that the force will act through the Center of resistance (CRe). Pre retraction and post retraction lateral cephalograms of each patient were taken, traced, superimposed and treatment outcomes, tooth movements and efficacy of mini implants as anchorage were evaluated. Paired and unpaired-t-tests were used for the data analysis.
Results: Translation was not seen in all the cases. Among 30 subjects, only 7 showed bodily movement, 11 showed controlled tipping and 12 showed uncontrolled tipping with retraction. Some amount of intrusion and distal tipping of maxillary first molars was observed with use of mini implants as anchorage units.
Conclusions: Location of CRe of consolidated unit of maxillary anterior teeth varies amongindividuals and depends on number of factors such as alveolar bone support, root morphology and tooth inclinations. Until strong conclusive clinical evidence is put forth, generalization of center of resistance location and assigning standard retraction hook dimensions to produce bodily movement of consolidated unit of maxillary anterior teeth is not advised.

INTRODUCTION

Anterior tooth retraction represents a fundamental phase of fixed orthodontic appliance treatment. Three dimensional control of anterior tooth movement and correct positioning of teeth are important for function, aesthetics and stability [1]. Orthodontic tooth movement is often achieved more efficiently when the tipping of the teeth is minimized. By definition, a force with a line of action passing through the centre of resistance of a tooth produces pure translation without rotation of the tooth[2]. One can predict the behaviour of any body in space if one knows the forces in relation to its centre of mass[3]. Efficient orthodontic tooth movements largely depend on an appreciation of the relationship between a line of action of force and the centre of resistance of a tooth.

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Kanomi[3] first introduced mini-screw implants (MSIs),which can be placed almost anywhere, in either the maxilla or the mandible, with a simple procedure.

Mechanically tooth is a supported rigid body, with its support in the surrounding tissue. If a tooth crown is loaded with a force couple, it will rotate around a well defined axis, the so called centre of resistance (CRe)[4]. This mechanical property has been used in a number of experimental and numerical studies to determine the position of CRe of single tooth, in part using highly idealized tooth models. Maxillary four incisor retraction or en masse retraction of anterior segment including canine teeth is used in the treatment of extraction or maxillary protrusion cases. Knowledge concerning the locations of the centres of resistance of various units of maxillary anterior teeth would contribute to successful treatment result and possibly a reduction in treatment time[5].

The use of power arms attached to the arch wire enables one to readily achieve controlled movement of the anterior teeth by enabling retraction forces to be directed through a point depending upon intended tooth movement. That is, the force system for the desired type of tooth movement such as lingual crown tipping, lingual root tipping, bodily movement can be easily carried out by attaching various heights of power arm to the arch wire in sliding mechanics[6,8]m Tominaga *et al*, by their 3D FEM study concluded that the placement of a power arm between the lateral incisor and canine enables orthodontists to gain better control of the anterior teeth in sliding mechanics[9]. To achieve bodily anterior tooth movement, the recommended length of the power arm is 5.5mm.Kim *et al*[9] concluded in their study that the power arm height should be 4.987mm when placed between lateral incisor and canine and 8.218mm when located between canine and first premolar to produce parallel translation of maxillary anterior teeth by retraction forces[10].

En masse retraction of six maxillary anterior teeth and tipping action built in anterior brackets in pre-adjusted edgewise appliance produces anchorage problems. Teeth subjected to translation are resistant to movement[6].The demand for speedy and efficient orthodontic treatment has been increasing in recent years. This resistance further demands the anchorage. To meet this demand, sliding mechanics in combination with implant anchorage has become more and more popular throughout the world [11, 16].

By using mini implants as anchorage and directing the retraction forces through centre of resistance of maxillary anterior segment, probably a good bodily translation of maxillary anterior teeth can be achieved thereby accomplishing favourable treatment outcome. This study is mainly aimed at evaluating the clinical applicability of proposed power arm length for translation of maxillary anterior teeth during en masse retraction using mini implants as anchorage.

MATERIAL AND METHODS

Thirty subjects with Angle's Class I or Class II malocclusions were included in the study. Patients were undergoing treatment with standard Pre-adjusted edgewise technique (MBT prescription, 3M Unitek), including extraction of maxillary first premolars. Class III malocclusion patients and patients undergoing non-extraction therapy were not included in the study. A consent form was obtained from each patient explaining the procedure and ethical committee clearance was obtained (NDC/PG/2013-14/EC/2014).

All the maxillary anterior teeth were consolidated into a single unit and retraction force was applied by active tie backs through power arm of length 5mm, positioned between maxillary lateral incisor and canine. Mini implants were used and the most suitable site for placement of mini implants was selected as the alveolar bone between the maxillary second premolar and first molar, preferably at the mucogingival junction.

In order to biometrically evaluate movement of the anterior teeth, cephalometric films were taken at the beginning and end of retraction. Local superimpositions of these pre and post retraction radiographic films done by best fit method. A co-ordinate system was set up on the pre retraction lateral cephalometric films. A line through Ptm, pterygomaxillary point and perpendicular to ANS-PNS plane (palatal plane) represents the Y-axis (Vertical L) and the ANS-PNS (palatal plane) as X –axis (Horizontal L). These axes served as references for the local superimpositions during angular and linear measurements in the vertical and horizontal directions.

Fifteen parameters were measured to examine the type of anterior tooth movement and efficacy of mini implants in producing the resulting tooth movement [Fig 1-2]. To determine the type of tooth movement, the center of resistance (CRe) was calculated. The point of intersection of pre and post treatment long axes of the central incisor was used for the determination of CRe. To measure the location of CRe, the root apex was accepted as the zero point.A positive value indicated a location of the CReapical to this point, and a negative value a location coronal to this point.

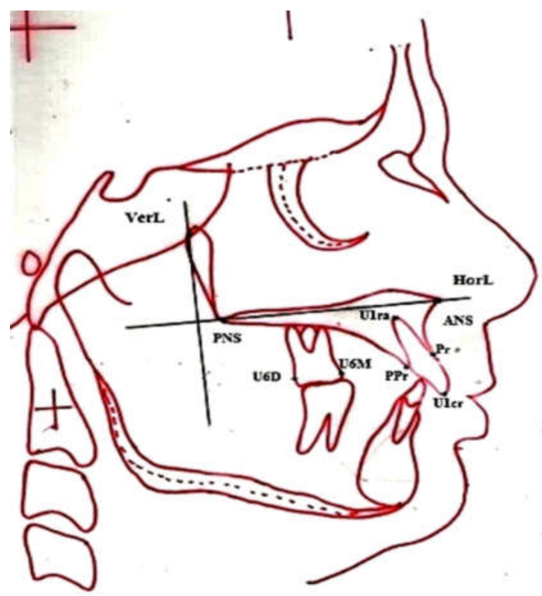

Figure 1 Cephalometric points and planes used in this study

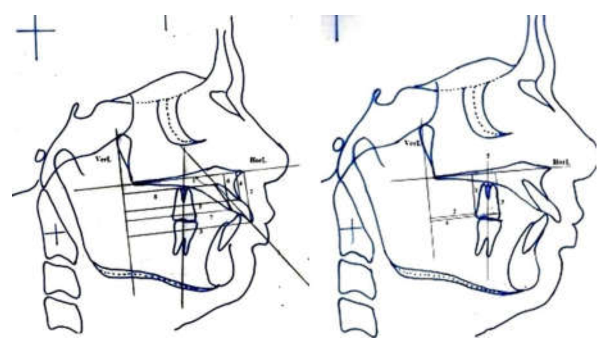

Figure 2 Linear and angular measurements on pre and post-retraction lateral cephalograms and to check the efficacy of mini implants as anchorage.

The subjects were divided into two groups according to the location of the CRe. In group 1 (eighteen patients), the CRe was apical to the root apex and in group 2 (twelve patients), coronal to the root apex. Paired-t-test was used to determine the differences between pre and post retraction values, and independent-t-test to determine the mean differences between the groups.

RESULTS

The statistical values of the pre and post retraction measurements, as well as statistical differences, are given intable1.U1/HorL angle,U1cr-VerL,Pr-VerL,PPr-HorL,PPr-VerL,U6D-HorL,U6D-VerL,U6M-HorL,U6M-VerL, over jetdemonstrated a significant decrease (P<0.05) and U1cr-HorL,Pr-HorL and U6 angle demonstrated significant increase (P<0.05).

In group 1, there was a significant decrease in U1ra-VerL distance, whereas in group 2, there was a significant increase in the U1ra-VerL distance (P<0.05).The decreases relating to U1/HorL angle and U1ra-VerL distance were found to be statistically significant between the groups (P<0.05 and P<0.001, respectively).

Table 1 Comparison of the differences between pre and post retraction values (n=30)

Parameters	Pre-retraction			Post retraction			P
	Mean	SD	SE	Mean	SD	SE	
U1/HorL(degrees)	126.67	3.594	.656	119.37	3.538	.646	.000**
U1cr-HorL(mm)	30.57	2.192	.400	31.87	2.403	.439	.000**
U1cr-VerL(mm)	69.73	3.787	.691	62.73	4.201	.767	.000**
U1ra-VerL(mm)	53.53	4.747	.867	53.47	6.004	1.096	.921NS
Pr-HorL(mm)	19.60	3.276	.598	20.80	2.999	.548	.000**
Pr-VerL(mm)	63.97	3.996	.729	59.50	3.998	.730	.000**
PPr-HorL(mm)	23.59	3.145	.584	21.66	2.781	.516	.000**
PPr-VerL(mm)	58.43	4.057	.741	54.63	4.760	.869	.000**
Root length(mm)	14.57	2.161	.394	-	-	-	-
Overjet(mm)	8.67	1.348	.246	3.33	.959	.175	.000**
U6D-HorL(mm)	21.90	2.023	.369	20.77	2.029	.370	.000**
U6D-VerL(mm)	22.10	2.264	.413	21.17	2.183	.399	.000**
U6M-HorL(mm)	21.77	2.112	.386	21.13	2.097	.383	.001*
U6M-VerL(mm)	33.30	2.037	.372	32.33	2.139	.391	.000**
U6 angle(degrees)	-2.83	1.416	.259	-4.37	1.650	.301	.000**

SE: standard error of the mean, SD: standard deviation, *p<0.05: Significant, **p<0.001; highly significant, NS: not significant

In 18 subjects, CRo was located apical to the root apex (Group 1), and in 12 subject's coronal to the root apex (Group 2). In 7 subjects, the CRo was infinite, i.e. the upper incisors demonstrated parallel movement [Table 2].

Table 2 The localization of the center of rotation (CRo) with respect to the root apex in all subjects (n=30). Negative values indicate the CRo lying coronal to the root apex

Number of cases	Localization of CRo (mm)	Number of cases	Localization of CRo (mm)
1	4	1	-2
2	∞	2	-4.5
3	2	3	-1
4	∞	4	-3
5	∞	5	-2.5
6	7	6	-5.5
7	1	7	-3
8	3.5	8	-1.5
9	11	9	-4
10	∞	10	-2.5
11	3	11	-1
12	5.5	12	-3
13	∞		
14	6.5		
15	∞		
16	3		
17	∞		
18	8.5		

For both groups, descriptive statistical values of pre and post retraction measurements are shown [Table 3]. The changes that occurred during retraction and the comparison of these changes within each group and between the groups are shown [Table 4].

In both the groups, there was a significant decrease in U1/HorL angle,U1cr-VerL,Pr-VerL,PPr-HorL,PPr-VerL,U6D-HorL,U6D-VerL,U6M-HorL,U6M-VerL, overjet and significant increase in U1cr-HorL,Pr-HorL and U6 angle (P<0.05).

DISCUSSION

Currently, miniscrews and miniplates are beingwidely used because of their small size and superiorityoverendosseous implants due to the fact thatthey can be immediately loaded.One end of orthodontic miniscrew is fixed to the corticalbone and the other end has attachments toengage orthodontic auxiliaries [7]. Several studies had been carried out to determine the center of resistance of maxillary anterior teeth. Pederson etalstated that the CRe of the upper incisors is located 5mm apical to the bracket level[17]. On the other hand, Gjessing reported that the CRe of the upper incisors is located 9-10mm gingival to the center of lateral bracket[18]. For the arch having the anterior 4 teeth connected, the CRe was located within the mid-sagittal plane, 6-mm apical and 4-mm posterior to a line perpendicular to the occlusal plane from the labial alveolar crest of the central incisor [2].

The center of resistance of consolidated unit of six maxillary anterior teeth is located 7mm apical to the interproximal bone level between central incisors according to VandenBulcke *et al*[19]. According to Kwangchul Choy, Kyung-HoKim and Charles J. BurstoneCRe of the upper anterior segment was located 14.5 mm apical and 9.5 mm distal from the incisal edge of the central incisors[20]. For the maxillary arch having the anterior 6 teeth connected, the CRe was located 13.5mm apical and 14 mm posterior to the incisal edge of the upper central incisor. The CRe of six maxillary anterior teeth was located vertically 12.2 mm (55.56%) apical to the incisal edges of the central incisors[21]. For parallel translation of anterior segment, the retraction force applied should pass through the CRe.

In sliding mechanics, retraction forces can be transferred to any height level on a power arm to move the tooth in a pre-programmed direction (eg, controlled crown-lingual tipping, bodily translation movement, and controlled crown-labial movement)[8].

Table 3 Pre and post- retraction descriptive values for both groups

Parameters	Group 1(n=18)						Group 2 (n=12)					
	Pre-retraction			Post-retraction			Pre-retraction			Post-retraction		
	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE	Mean	SD	SE
U1/HorL(degrees)	126.33	3.985	.939	120.11	3.740	.882	127.17	3.010	.869	118.25	3.019	.871
U1cr-HorL(mm)	30.11	2.083	.491	31.33	2.223	.524	31.25	2.261	.653	32.67	2.535	.732
U1cr-VerL(mm)	70.00	4.116	.970	63.00	4.537	1.069	69.33	3.367	.972	62.33	3.798	1.096
U1ra-VerL(mm)	53.89	5.075	1.2	51.83	6.401	1.509	53.00	4.369	1.261	55.92	4.562	1.317
Pr-HorL(mm)	19.11	3.376	.796	20.33	3.049	.719	20.33	3.114	.899	21.50	2.908	.839
Pr-VerL(mm)	64.17	4.554	1.07	59.56	4.409	1.039	63.67	3.143	.907	59.42	3.476	1.003
PPr-HorL(mm)	23.35	3.200	.776	21.00	2.525	.612	23.92	3.175	.917	22.58	2.968	.857
PPr-VerL(mm)	58.72	4.599	1.08	54.89	5.389	1.270	58.00	3.219	.929	54.25	3.817	1.102
Root length(mm)	14.33	2.275	.536	-	-	-	14.92	2.021	.583	-	-	-
Overjet(mm)	8.61	1.243	.293	3.28	1.07	.253	8.75	1.545	.446	3.42	.793	.229
U6D-HorL(mm)	22.11	1.875	.442	20.83	2.121	.500	21.58	2.275	.657	20.67	1.969	.569
U6D-VerL (mm)	22.33	2.000	.471	21.67	1.749	.412	21.75	2.667	.770	20.42	2.610	.753
U6M-HorL(mm)	21.56	2.007	.473	20.94	2.155	.508	22.08	2.314	.668	21.42	2.065	.596
U6M-VerL(mm)	32.94	1.662	.392	32.11	1.844	.435	33.83	2.480	.716	32.67	2.570	.742
U6 angle(degrees)	-2.44	1.977	.466	-4.22	1.83	.432	-3.08	.996	.288	-4.58	1.379	.398

SE: standard error of the mean, SD: standard deviation, Group 1: center of rotation located apical to the root apex, Group 2: center of rotation located coronal to the root apex.

Table 4 The mean changes during the retraction period and comparisons between the groups

Parameters	Group 1 (n=18)				Group 2 (n=12)				*P*
	D	SD	SE	*P*	D	SD	SE	*P*	
U1/HorL(degrees)	-6.22	2.340	0.552	.000**	-8.92	1.832	0.529	.000**	.002*
U1cr-HorL(mm)	1.19	0.770	0.181	.000**	1.42	0.733	0.212	.000**	.437 NS
U1cr-VerL(mm)	-7.00	0.748	0.176	.000**	-6.92	1.062	0.307	.000**	.802 NS
U1ra-VerL(mm)	-2.06	3.476	0.819	.021*	2.92	0.702	0.203	.000**	.000**
Pr-HorL(mm)	1.14	0.819	0.193	.000**	1.33	0.807	0.233	.001*	.527 NS
Pr-VerL(mm)	-4.58	1.286	0.303	.000**	-4.29	1.764	0.509	.000**	.604 NS
PPr-HorL(mm)	-2.28	1.437	0.339	.000**	-1.33	1.052	0.304	.002*	.061 NS
PPr-VerL(mm)	-3.83	1.847	0.435	.000**	-3.75	1.765	0.509	.000**	.903 NS
Overjet(mm)	-5.33	1.485	0.350	.000**	-5.33	1.249	0.361	.000**	1.00 NS
U6D-HorL(mm)	-1.22	1.342	0.316	.001*	-0.88	0.908	0.262	.002*	.440 NS
U6D-VerL (mm)	-0.56	1.056	0.249	.014*	-1.21	0.542	0.156	.000**	.059 NS
U6M-HorL(mm)	-0.67	0.970	0.229	.012*	-0.50	1.022	0.295	.050*	.655 NS
U6M-VerL(mm)	-0.89	0.719	0.169	.002*	-1.14	0.760	0.219	.001*	.364 NS
U6 angle(degrees)	1.74	1.443	0.340	.000**	1.46	0.838	0.242	.000**	.541 NS

D: mean difference, SE: standard error of the mean, SD: standard deviation, *p<0.05: Significant, **p<0.001: highly significant, NS: not significant, Group 1: center of rotation located apical to the root apex, Group 2: center of rotation located coronal to the root apex.

Hence, sliding mechanics have the potential to simplify the force system for tooth movement because the horizontal level of retraction force can be freely adjusted by soldering various lengths of power arms to an arch wire. Kim *et al* proved that with power arm of length 5mm soldered to the arch wire between the maxillary lateral incisor and canine and application of retraction forces could direct the retraction forces through the center of resistance of maxillary anterior teeth segment using finite element model analysis[10].

Hence taking into consideration the findings of Kim *et al*, we used a power arm of length 5 mm soldered between maxillary lateral incisor and canine in our study to act as point of force application from anchorage unit (mini implant) to direct the forces through an assumed center of resistance. Forces acting through center of resistance and producing bodily movement of the teeth are associated with higher degrees of stresses in the periodontal ligament. Optimal forces increase in tooth movement approaching translation[22]. This further increases the anchorage demands. Hence taking into consideration of anchorage for translatory movement of teeth; we used mini-screws as source of absolute anchorage.

In our study, the inclination of upper incisors demonstrated an average decrease of 7.3 degrees, the upper incisor crown moved on an average by 7 mm posteriorly. Prosthion point and posterior Prosthion point moved each by 4.47mm and 3.8mm respectively and followed the crown movement.

Upper incisor crown moved vertically downward by 1.3 mm and also Prosthion point moved downward by 0.8mm along with the crown due to apposition. But the posterior Prosthion point showed upward movement on an average by 1.93mm due to resorption. Average reduction in overjet was 5.34mm. All these changes were statistically significant in the entire sample [Table 1]. These findings were similar to that observed by T. Turk *et al* who evaluated clinically the movement of consolidated unit of four maxillary incisors[1]. But in our study upper incisor root apex to vertical reference plane was not significantly differing with retraction. This finding is different from that of T.Turk *et al*. [1]. This might be mostly due to controlled tipping type of movement as a result of force being acting close to the center of resistance of six teeth unit that is found to be located more incisal than that of four tooth unit which is supposed to be located more apically[5].

Upadhyayand co-workers, showed that there was net intrusive effect on maxillary first molar but was not statistically significant, and distal tipping of maxillary first molar which was statistically significant[23]. But in our study all the changes in the maxillary molars with respect to both horizontal and vertical reference planes were statistically significant, and matching with the study by Upadhyay *et al* [23].

Although the line of action passed through the center of resistance (as assumed), superimposition of pre retraction and post retraction lateral cephalograms revealed that out of 30 cases, only 7 patients showed bodily movement, 11 patients showed controlled tipping and 12 patients showed uncontrolled tipping. For this reason, the subjects were divided into two groups according to the location of CRe and compared according to the type of tooth movement and factors affecting the tooth movement [Table 2].

The upper incisors tipped posteriorly 6.2 and 8.9 degrees in groups 1 and 2 respectively [Table 4]. This difference was found to be statistically significant, and was consistent with less posterior root apex movement in group 2. The differences in bone support, root morphology and tooth inclination change the location of CRe[1]. The increase in root length and decrease in the alveolar bone height cause an apical movement of CRe. The CRe moves 1.3 mm to the apical with a root length increase of 50 percent and the CRe moves 4mm apical with the alveolar bone height decrease of 50 percent[24].

In the present investigation, comparison of pre retraction root lengths, alveolar bone heights as indicated by Prosthion and posterior Prosthion points to horizontal reference plane and axial inclinations of incisors showed no statistically significant differences between the two groups. Yet there were statistically significant differences between the two groups with respect to mean changes in the axial inclination of incisors and maxillary incisor root apex movement. These differences might be due to forces acting close to the center of resistance in few cases which expressed controlled tipping and through the center of resistance in few cases that expressed translation thereby producing little differences in the sagittal position changes in the root apex in group 1. This finding is matching with that of Sia *et al*, who concluded that power arm length of 3 to 5 mm produce controlled lingual-crown tipping (with the apex as the center of rotation) for efficient anterior tooth retraction[25]. Those in which the forces acting away from the root apex and well below the center of resistance expressed uncontrolled tipping, thereby producing significant sagittal position changes in the root apex.

One study showed that with the use of power arm of length 5.5mm, bodily movement occurred[9]. Another study showed that power arm of length 5 mm produced controlled lingual crown tipping[25]. Yet another study showed that the power arm of length 5 mm produced translation[10].Our study results indicate that in only around 60% of total sample retraction forces were passing closer to center of resistance. In about 40% of total sample, the retraction forces were passing well below the center of resistance as evidenced by uncontrolled tipping observed in these cases.

These variable findings raises questions concerning the location of CRe in other studies and the applicability of power arm of length 5mm for translatory movement of anterior teeth, clinically. The 3D finite element analysis is only theoretical and has limitations in consideringdifferent physiologic responses in each patient. Even with the model designed by average measurements for every property, the result of finite element analysis will be constricted to the initial short-term response just at the time of force application, ignoring biological events of tissue remodelling[21]. VandenBulcke *et al* stated that structural and spatial relationships of the dentofacial components are different among subjects and this difference may affect the center of resistance localization[19].

The difference in the tooth movement of two dry human skulls was explained by the width of artificial periodontal ligament (PDL) and bone elasticity. It is stated that bone – root anatomy and PDL morphology might affect the location of the CRe in vivo[19]. Morphology of the roots [22], levels of alveolar bone [26], magnitude of force application [27], palatal bone height [5], incisor inclination [1] and direction of tooth movement [28] significantly affects the location of center of resistance.

Reference points used to determine CRe localization vary. Pederson *et al*[17] used the bracket position, Matsui *et al*[2] the labial alveolar crest of the central incisor and VandenBulcke *et al*[19] the interproximal bone level. The variation in reference points and the difficulty of clinical observation of some of these reference points might lead to problems for the accurate determination of the CRe. Moreover S.Reimann *et al* disproved the classical view of combined center of resistance and suggested omission of planning orthodontic treatment based on this view[4].

CONCLUSION

Location of CRe of consolidated unit of maxillary anterior teeth varies from person to person and it depends on number of factors such as alveolar bone support, root morphology and tooth inclinations. Obviously the height at which retraction forces should be applied to make them pass through the center of resistance also varies. Unless strong conclusive clinical evidence is put forth, generalization of center of resistance location and assigning standard retraction hook dimensions to produce bodily movement of consolidated unit of maxillary anterior teeth is not advised. Rather customization of the power arm dimensions depending upon the clinical circumstances is advisable. Hence, the examination of relationship between the individual CReand the line of action of force, the observation of tooth movement occurring during treatment and changes in the treatment mechanics would be helpful in obtaining desired tooth movement.

References

1. Türk T, Elekdag-Türk S, DinçerM.Clinical evaluation of centre of resistance of the upper incisors during retraction. *Eur J Orthod*. 2005; 27:196-201.
2. Matsui S, Caputo AA, Chaconas SJ, Kiyomura H.Center of resistance of anterior arch segment. *Am J OrthodDentofacialOrthop*. 2000; 118:171-8.
3. Tozlu M, Nalbantgil D, Ozdemir F. Effects of a newly designed apparatus on orthodontic skeletal anchorage. *Eur J Dent*. 2013; 7:83-8.
4. Reimann S, Keilig L, Jäger A, Bourauel C. Biomechanical finite-element investigation of the position of the centre of resistance of the upper incisors. *Eur J Orthod*.2007; 29:219-24.
5. Yoshida N, Koga Y, Mimaki N, Kobayashi K. In vivo determination of the centers of resistance of maxillary anterior teeth subjected to retraction forces. *Eur J Orthod*.2001; 23: 529-34.
6. Smith RJ, Burstone CJ. Mechanics of tooth movement. *Am J Orthod Dentofacial Orthop*. 1984; 85: 294-307.
7. Nalbantgil D, Tozlu M, Ozdemir F, Oztoprak MO, Arun T. FEM analysis of a new miniplate: stress distribution on the plate, screws and the bone. *Eur J Dent*.2012; 6: 9-15.
8. Sia S, Koga Y, Yoshida N. Determining the Center of Resistance of Maxillary Anterior Teeth Subjected to Retraction Forces in Sliding Mechanics. *Angle Orthod*. 2007; 77: 999-1003.

9. Tominaga JY, Tanaka M, Koga Y, Gonzales C, Kobayashi M, Yoshida N. Optimal loading conditions for controlled movement of anterior teeth in sliding mechanics. *Angle Orthod*. 2009; 79: 1102-7.
10. Kim T, Suh J, Kim N, Lee M. Optimal conditions for parallel translation of maxillary anterior teeth under retraction force determined with the finite element method. *Am J Orthod Dentofacial Orthop*. 2010; 137:639-47.
11. Chae JM. Unusual extraction treatment of Class I Bialveolar protrusion using Micro implant anchorage. *Angle Orthod*. 2007; 77: 367-375.
12. Jung MH, Kim TW. Biomechanical considerations in treatment with Miniscrew anchorage. Part 1: sagittal plane. *J Clin Orthod*. 2008; 42: 79-83.
13. Jung MH, Kim TW. Biomechanical considerations in treatment with Miniscrew anchorage. Part 3: Clinical cases. *J Clin Orthod*. 2008; 42: 329-37.
14. Park HS, Kwon TG. Sliding mechanics with Microscrew implant anchorage. *Angle Orthod*.2004; 74: 703–10.
15. Park HS, Yoon DY, Park CS, Jeoung SH. Treatment effects and anchorage potential of sliding mechanics with titanium screws compared with the Tweed-Merrifield technique. *Am J Orthod Dentofacial Orthop*. 2008; 133: 593-600.
16. Sugawara J, Kanzaki R, Takahashi I, Nagasaka H, Nanda R.Distal movement of maxillary molars in non growing patients with the skeletal anchorage system. *Am J Orthod Dentofacial Orthop*. 2006; 129:723-33.
17. Pedersen E, Isidor F, Gjessing P, Andersen K. Location of centres of resistance formaxillary anterior teeth measured on human autopsy material. *Eur J Orthod.* 1991; 13:452-458.
18. Gjessing P. Controlled retraction of maxillary incisors. *Am J Orthod Dentofacial Orthop* 1992; 101: 120-31.
19. VandenBulcke MM, Burstone CJ, Sachdeva RC, Dermaut LR. Location of the centers of resistance for anterior teeth during retraction using the laser reflection technique. *Am J Orthod Dentofacial Orthop*. 1987; 91: 375-84.
20. Choy K, Kim KH, Burstone CJ. Initial changes of centres of rotation of the anterior segment n response to horizontal forces. *Eur J Orthod*.2006; 28: 471-4.
21. Jang HJ, Roh WJ, Joo BH, Park KH, Kim SJ, Park YG. Locating the center of resistance of maxillary anterior teeth retracted by Double J retractor with palatal miniscrews. *AngleOrthod*. 2010; 80:1023-8.
22. Choy K, Pae EK, Park Y, Kim KH, Burstone CJ. Effect of root and bone morphology on the stress distribution in the periodontal ligament. *Am J Orthod Dentofacial Orthop*. 2000; 117:98-105.
23. Upadhyay M, Yadav S, Patil S. Mini-implant anchorage for enmassse retraction of maxillary anterior teeth: A clinical Cephalometric study. *Am J Orthod Dentofacial Orthop* 2008; 134: 803-10.
24. Tanne K, Nagataki T, Inoue Y, Sakuda M, BurstoneCJ.Patterns of initial tooth displacements associated with various root lengths and alveolar bone heights. *Am J Orthod Dentofacial Orthop*. 1991; 100:66-71.
25. Sia S, Shibazaki T, Koga Y, Yoshida N.Experimental determination of optimal force system required for control of anterior tooth movement in sliding mechanics. *Am J Orthod Dentofacial Orthop*. 2009; 135: 36-4.
26. Geramy A.Alveolar bone resorption and the center of resistance modification (3D-analysis by means of the finite element method). *Am J Orthod Dentofacial Orthop*. 2000; 117: 399-405.
27. Yoshida N, Koga Y, Kobayashi K, Yamada Y, Yoneda T.A new method for qualitative and quantitative evaluation of tooth displacementunder the application of orthodontic forces using magnetic sensors. *Med Eng Phys*.2000; 22:293-300.
28. Meyer BN, Chen J, Katona TR. Does the center of resistance depend on the direction of tooth movement? *Am J Orthod Dentofacial Orthop*. 2010; 137:354-6.

How to cite this article:

Abdul Khaliq *et al* (2017) 'Clinical Evaluation of Center of Resistance of Maxillary Anterior Teeth During En Masse Retraction with Mini Implant Anchorage', *International Journal of Current Advanced Research,* 06(12), pp. 7976-7981. DOI: http://dx.doi.org/10.24327/ijcar.2017.7981.1265

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