Wolters Kluwer Issue 01 • January-March 2022 • Volume 33 Medknow

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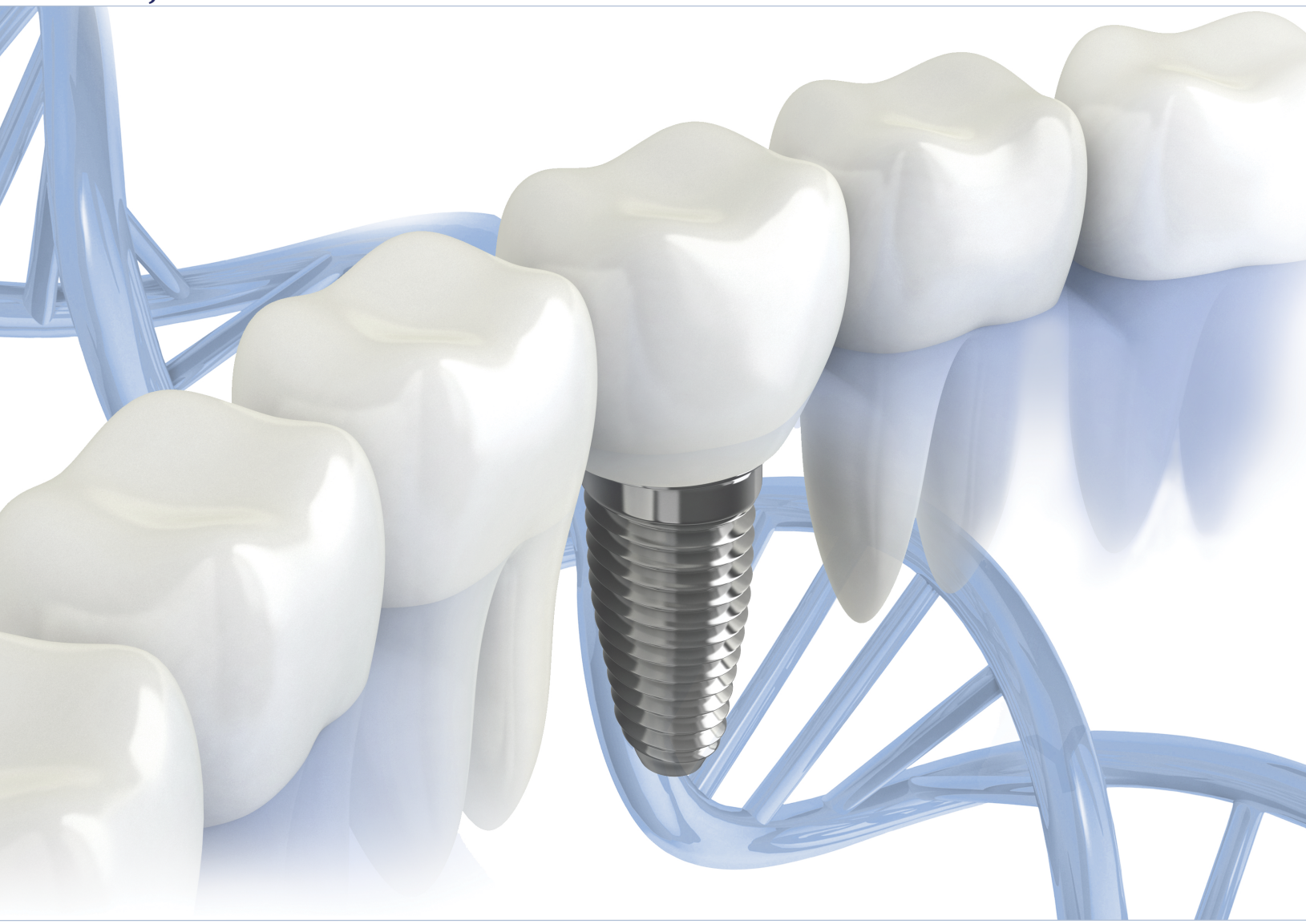

Official Publication of

Indian Society for Dental Research
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International Association for Dental Research - Indian Division
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Original Article

Post-Expansion and End of Treatment Outcomes of Semi-Rapid Maxillary Expansion with a Modified Removable Appliance

Abstract

Context: Maxillary expansion is the mainstay therapy for maxillary transverse deficiency. There has been a constant search for the most effective yet biologically friendly method of maxillary expansion, alternatives being, slow, rapid and semi rapid. **Aims:** The purpose of this study was to explore the outcome of palatal expansion achieved using a removable plate and low continuous forces brought about by a semi rapid screw activation protocol. **Settings and Design:** Retrospective study. **Methods and Material:** Plaster models of 56 consecutive patients treated for maxillary expansion were obtained pre-treatment (T_0), post-expansion (T_1), and post fixed appliance treatment (T_2). The radiographic images of the models were traced using Image J software. Linear and angular measurements were evaluated to measure transverse change. **Statistical Analysis Used:** Interclass Correlation Coefficient [ICC] and Dahlberg's formula were used for reliability test. The differences in the mean values between the three duration groups [T_0, T_1 and T_2] were analysed using Analysis of Variance (ANOVA). For multiple comparisons, a *post hoc* Tukey honestly significant difference (HSD) test was performed. **Results:** Significant increase in inter-molar, alveolar and palatal linear widths were observed from T_0 to T_1 with significant relapses from T_1 to T_2, with an overall net gain remaining at T_2. Similarly, significant increases in all angular measurements were observed from T_0 to T_1 with significant relapses from T_1 to T_2 and an overall insignificant change at T_2 as compared to T_0. **Conclusion:** The appliance and protocol were effective in producing transverse expansion with minimal molar and alveolar tipping.

Keywords: *Airway, maxillary expansion, maxillary transverse deficiency, removable appliance, semi rapid maxillary expansion, sleep*

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Received : 05-03-2021
Revised : 20-08-2021
Accepted : 06-10-2021
Published : 09-08-2022

Access this article online

Website: www.ijdr.in

DOI: 10.4103/ijdr.ijdr_210_21

Quick Response Code:

Introduction

Early treatment of transverse maxillary deficiency aims to expand the maxilla, eliminate the functional shift, and thereby restore condylar and facial symmetry.[1] Palatal expansion can either be rapid, semi-rapid or slow maxillary expansion.[2-4] The most popular method is rapid maxillary expansion (RME).[5,6] RME is usually defined as a screw activation of two turns per day. Advocates of rapid maxillary expansion believe that it results in minimum dental movement (tipping) and maximum skeletal movement.[2] However, the major concern with RME is the deleterious effects such as micro trauma of the midpalatal suture, relapse and other unwanted consequences.[7-10] Semi-rapid Maxillary Expansion (SRME) has been defined as 1 mm to 1.5 mm expansion/week producing lower forces.[3,11] It is believed that slow expansion allows for more physiologic adjustment to sutural separation.[12,13] There are very few studies on the effects of expansion using a removable appliance.[11] The aim of the present investigation was to use radiographs of plaster models to evaluate post expansion and post fixed appliance changes in palatal base width, inter-alveolar width, inter-molar width, dentoalveolar inclination and molar inclinations in subjects treated by SRME using a removable appliance.

Subjects and Methods

The pre expansion (T_0), post expansion (T_1) and post fixed appliance [at debond] (T_2) study models of 56 consecutively treated patients (22 males and 34 females) with an age range of 12 to 15 years were selected for this study. Informed consent was obtained from the study subjects' parents. The study was approved by the Institutional

How to cite this article: Banker AM, Thakkar MN, Desai BB, Huja SS. Post-expansion and end of treatment outcomes of semi-rapid maxillary expansion with a modified removable appliance. Indian J Dent Res 2022;33:63-8.

Ethics Committee of Ahmedabad Dental College and Hospital, Ahmedabad (Regd. No. E/10984/AHD) Date: 13-08-2013.

Inclusion criteria were:

Patients having a narrow palate (having inter-palatal molar width less than 34.9 mm) and whose treatment plan included a palatal expander,[7] patients in the age group of 12 to 15 years.

Exclusion criteria were:

Syndromic and cleft patients, patients who had previous orthodontic treatment, patients with severe skeletal discrepancies.

Appliance

Each patient was treated with a modified removable screw plate with six Adams clasps and an 11 mm jackscrew (Dentaurum, GmbH & Co, KG, and Germany) placed at the deepest part of the palate [Figure 1a]. Every patient was treated with the appliance described above and by the same operator.

A. Removable appliance was chosen because of the following reasons:
   Ease of insertion and removal, fewer laboratory steps, ease of activation, ease of maintaining oral hygiene, less bulk, fewer speech impediments, and cost effectiveness.
B. Modification of the conventional Schwarz plate was done because:
   a. A labial bow restricts expansion, while two Adams added anteriorly helps in anterior expansion. This is particularly useful in crowded or V shaped arches.
   b. Six Adams clasps distribute the forces equally both anteriorly as well as posteriorly, so there is less damage to the anchor teeth.
   c. There is more retention so the plate is stable and does not lift up due to activation.
C. Change in activation protocol was chosen because:
   a. RME produces extremely heavy forces on the anchor teeth with danger of trauma, pain, bone resorption as well as fenestrations and micro damage with tears and haemorrhages. Chances of relapse are also more.
   b. SME produces forces too low for skeletal changes.
   c. The authors have chosen a force level between RME and SME called SRME to get the benefits of both the protocols; namely, changes at the skeletal level with minimal dental tipping and less damage to anchor teeth due to high forces.
   d. Another benefit of the unique appliance used in the present study and activation protocol is that stable remodelling of the palatal vault is seen due to the biomechanical load of the acrylic plate on the palate.

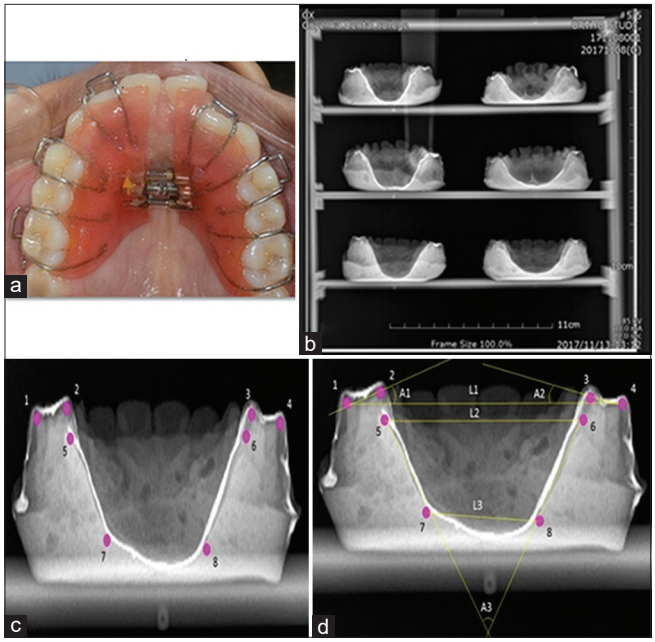

Figure 1: (a) Modified removable screw plate. (b) Radiographic image of the cabinet with models. (c) Reference points used for evaluation. (d) Linear and angular parameters measured

The screw activation protocol was semi rapid expansion i.e., 1/8th turn of a full rotation per day which delivers constant and low forces. Patients and parents were instructed on the activation of the screw. The patients were advised to wear the plate for 24 hours including meal times, except during brushing. They were instructed to maintain adequate oral hygiene and to brush even after meals. Expansion was continued until the palatal cusps of the upper molars touched the buccal cusps of the lower molars (around 3.5 ± 0.5 months). There was no retention period after achieving expansion and all the patients were placed on fixed appliances immediately. Preadjusted fixed appliances (0.022 × 0.028″ slot) were given to each patient for 18 ± 2 months prior to debonding. Plaster models were prepared before the start of treatment (T_0), after expansion with a removable appliance (T_1) and at the end of fixed appliance treatment (T_2) for each subject. Radiographs of the plaster models were taken according to the method described previously.[14] Radiographs were taken so that the outline of the palate and teeth could be demarcated clearly and the linear and angular parameters could be accurately measured. A line was drawn on the maxillary study models using a paint-brush and barium sulphate solution. The line started in the vestibular sulcus of one side, passing through the gingival margin of the mesio-buccal cusp of the upper right first molar, continuing through the tips of the mesio-buccal and mesio-palatal cusps of that tooth, crossing the palatal vault between the first molars, and ending at the vestibular gingival margin of the left molar on the other side. After this step the models were placed in a plastic cabinet which allowed X-rays to pass freely, and then a radiographic image of the cabinet was obtained [Figure 1b]. The radiograph was taken using

cephalostat at the distance of five feet from the X-ray source in order to maintain true value of the measurements. In order to achieve standardisation and to obtain an image without distortion, special attention was given to the following points:

1. The parallelism of the posterior edges of the study models and barium sulphate lines to the film plane.
2. The parallelism of model bases to the horizontal plane.

The digital radiograph was then transferred to Image J, an open source Java based image processing and analysis program for evaluation.[15] The reference points [Figure 1c] used for the evaluation of dentoalveolar inclination were right and left mesio-buccal cusp tips (Point 1, 4), right and left mesio-palatal cusp tips (Point 2, 3), right and left upper alveolar points i.e., midpoint of the junction between alveolar process and palatal gingiva of the first molar (Point 5, 6), right and left lower alveolar points i.e., midpoint of the junction between alveolar process and palatal shelf (Point 7, 8). Three linear measurements (L1, L2 and L3) and three angular measurements (A1, A2 and A3) were taken for each model at T_0, T_1 and T_2 [Figure 1d] on the digital radiograph using the Image J Analyze – measure tools [Table 1]. Based on the reference scale in the digital x-ray image, the scale in the ImageJ software was calibrated.

Statistical analysis

Twenty pilot study samples of models were analysed to obtain standard deviation and standard error to calculate adequate sample size. The standard deviation (σ) and the standard error (E) was found to be 2.1 mm and 0.55 mm respectively. The confidence interval was set at 95%. Z value equivalent to 95% confidence is 1.96. The sample size calculation is as below:

$n = Z^2 * \sigma^2 / E^2$

$= 1.96^2 * 2.1^2 / 0.55^2$

$= 3.84 * (4.41/0.30)$

$= 3.84 * 14.7$

$= 56.$

Hence a minimum sample size of 56 was considered in this study.

The statistical analysis was performed using SPSS software version 16.0 (Chicago, SPSS Inc.) and Microsoft Excel (2010). In order to evaluate measurement errors, repeat measurement of randomly selected 20 digital images of the casts was conducted by same evaluator after period of two weeks. The reliability of the measurements was obtained by using Interclass Correlation Coefficient [ICC] and Dahlberg's formula. Cronbach alpha score was used to determine the reliability of the measurements. Reliability is considered acceptable if the interclass correlation are greater than 0.80. The interclass correlation for each measured variable was showing the value above 0.80 [Table 2]. Hence the original measurements were deemed reliable. Data were analysed for normal distribution using Shapiro–Wilk's test. On analysis, it was found that all the variables followed normal distribution; hence parametric test was performed to test the statistical significance before, during and after treatment mean values. Descriptive statistics including mean and standard deviation [SD] were calculated for all the parameters using Microsoft Excel. The differences in the mean values between the three duration groups [T_0, T_1 and T_2] were analysed using Analysis of Variance (ANOVA). For multiple comparisons, a *post hoc* Tukey Honestly Significant Difference (HSD) test was performed.

Table 1: Description of the linear and angular parameters used in the study

Parameters*	Description
Linear measurements	
L1	Inter molar width
L2	Inter alveolar width
L3	Palatal base width
Angular measurements	
A1	Right molar tipping angle
A2	Left molar tipping angle
A3	Alveolar tipping angle

*L - Linear; A –Angular

Table 2: Intra observer variations and the measurement error values of the measured parameters

Parameters measured	Duration	Dalhberg's value	ICC value
Inter-molar width (mm.)	T_0	0.621	0.972
	T_1	0.771	0.965
	T_2	0.655	0.975
Alveolar width (mm.)	T_0	0.820	0.966
	T_1	0.831	0.958
	T_2	0.807	0.964
Palatal width (mm.)	T_0	0.796	0.956
	T_1	0.815	0.948
	T_2	0.775	0.953
Right molar inclination (°)	T_0	0.795	0.964
	T_1	0.766	0.970
	T_2	0.771	0.962
Left molar inclination (°)	T_0	0.766	0.942
	T_1	0.752	0.954
	T_2	0.779	0.941
Alveolar angle (°)	T_0	0.899	0.932
	T_1	0.857	0.947
	T_2	0.869	0.939

T_0=Pre-treatment, T_1=Post-expansion, T_2=Post fixed appliance treatment. ICC – Interclass correlation

Results

Descriptive statistics for all the measured parameters and their statistical significance is summarised in Table 3. Results of ANOVA [Table 3] demonstrated that all

parameters showed a significant difference ($P < 0.05$) among the duration groups [T_0, T_1, T_2]. A significant increase in the mean values of all the parameters from T_0 to T_1 was seen, except in alveolar angle, where the increase was insignificant ($P = 0.011$).

The total inter-molar width increased by 2.67 mm, the change in inter-alveolar width showed an increase of 3.04 mm while the palatal base width was increased by 3.69 mm. post treatment. In the angular parameters, the right and left molar inclination showed a change of 1.53° and of 0.21° respectively. The palatal alveolar angle showed a net decrease of 4.30° [Table 4].

Discussion

An estimated 25-30% of all orthodontic patients can benefit from maxillary expansion, and 95% of Class II cases can be improved by molar rotation, distalisation, and expansion.[16,17]

Expansion is usually accompanied by the buccal tipping movement of the alveolar process and posterior teeth.[7-9,18] A variety of factors such as the type of appliance, age of patient, mode of activation, resistance offered by skeletal and soft tissues affect the amount of dentoalveolar tipping.[19] Optimum forces are those which were high enough give expansion and at the same time not so large so as to cause tissue damage. The modification described here was unique and to the best of the authors' knowledge, presented for the first time in the literature for this specific purpose.

Method of assessment

The methodology in this present study was chosen because it gives a clear view of the palate without radiation to the patient and no superimposition of structures. It is also possible to measure both linear distances as well as angulations using this method.

Increase in the inter-molar width shows the total amount of skeletal, dentoalveolar and dental effect produced by the appliance. All the linear parameters showed an increase at the end of expansion (T_1). At the end of 18 months post fixed appliances (T_2) some relapse was seen, but still a total gain in width was seen as compared to T_0. A total increase of 2.67 mm, 3.04 mm, 3.69 mm was seen at the inter molar, inter alveolar and palatal base width at T_2. Thus an ascending amount of expansion from the molars to the palatal base was seen. The significant amount of change at the palatal base ($P < 0.001$) was an encouraging finding. This could be because the placement of the screw in the depth of palate as well as the acrylic coverage of the appliance would direct the force vector to the centre of resistance of the maxilla, leading to movement of the maxillary halves in a more bodily fashion.[20] Three angulations were assessed, namely angulations of the palatal alveolar shelves and angulations of the left and right molars. The molar angulations showed an increase at the end of expansion, but decreased again at the end of treatment. It was seen that the dental tipping reverted back to almost the original values as in T_0 at the end of fixed appliance phase, likely due to the inbuilt torque of the pre adjusted appliances. A surprising find was in the alveolar inclination. It showed an increase of 1.46° post expansion, but decreased by 5.75° at the end of treatment.

Table 3: Descriptive statistics of the measured parameters at different time period

Parameters	T_0		T_1		T_2		Significance
	Mean	SD	Mean	SD	Mean	SD	
Intermolar width (mm.)	54.46	2.78	59.34	2.69	57.12	2.82	0.000*
Alveolar width (mm.)	36.57	2.72	41.04	2.48	39.6	2.64	0.000*
Palatal width (mm.)	15.76	3.05	20.46	3.2	19.45	2.95	0.000*
Right molar inclination (°)	10.35	5.73	13.56	6.31	8.82	7.27	0.001*
Left molar inclination (°)	7.59	8.03	12.93	7.67	7.8	5.72	0.000*
Alveolar angle (°)	78.85	9.91	80.3	10.57	74.55	10.52	0.011*

(*Significant at $P<0.05$), T_0=Pre-treatment, T_1=Post-expansion, T_2=Post fixed appliance treatment, SD=Standard Deviation

Table 4: Mean difference in the measured values between T_0, T_1 and T_2

Parameters	T_1-T_0			T_2-T_1			T_2-T_0		
	Mean	SD	Significance	Mean	SD	Significance	Mean	S3D	Significance
Inter-molar width (mm.)	4.88	2.79	0.000	-2.22	2.4	0.000	2.660	2.440	0.000*
Alveolar width (mm.)	4.48	2.12	0.000	-1.44	2.03	0.006	3.030	2.210	0.000*
Palatal width (mm.)	4.71	2.69	0.000	-1.01	2.2	0.192	3.690	2.400	0.000*
Right molar inclination (°)	3.21	6.71	0.025	-4.74	6.9	0.000	-1.530	8.070	0.427
Left molar inclination (°)	5.34	9.44	0.000	-5.13	8.6	0.001	0.210	10.060	0.987
Alveolar angle (°)	1.46	4.66	0.738	-5.75	7.07	0.011	-4.300	8.180	0.076

*significant at $P<0.05$), T_0=Pre-treatment, T_1=Post-expansion, T_2=Post-fixed appliance treatment, SD=Standard Deviation; Sig=Significance

This change was 4.29° less than even the pre-treatment values. Alveolar angle decreased more than pre-treatment readings because the expansion at points 7 and 8 (palatal vault) was more than the expansion at points 5 and 6 (inter molar distance). This suggests that increase in palatal base width was more than the change in the alveolar width leading to a more parallel configuration and a decrease in angulations. One explanation is that more expansion occurs at the level of skeletal bases. Thus it can be seen that the increase in linear distances, not just at the molar level but even at the alveolar and palatal base level was found to be stable even 18 to 21 months post expansion. One can compare this with studies on RME by Lagravere *et al*.[18] and others who have noted that only 25% of the expansion is retained after treatment. A recent study has stated that SRME should be preferred to overcome the disadvantages of RME.[21] In the appliance used in this study, care was taken to see that the activation of the plate was not more than the biological width of the mid palatal suture which is 0.2 mm. Studies have shown that slow expansion procedures allow physiologic adjustments and reconstitution of the sutural elements over a period of about 30 days.[12,22] McAndrews demonstrated that the application of light, continuous forces in areas of periosteal growth allows normal arch dimensions to develop at any age without undue tipping of the abutment teeth.[23] The increase in the transverse dimension of the palate appears to be the result of lateral translation and physiologic remodelling of the palate induced by biomechanical load of the acrylic plate due to low constant forces. Thus it can be seen that the expansion was achieved at the end of treatment with negligible tipping movements [Figure 2]. The appliance was not bulky and so was very well tolerated by the patients. None of the patients complained of pain or discomfort. It was easier to activate the screw outside the oral cavity. Oral hygiene was better maintained as the patient could remove the plate during brushing. All the three components of malocclusion i.e., the vertical, sagittal and the transverse dimensions should be corrected to achieve a good orthodontic finish, therefore expansion is an important part of a clinician's treatment plan. Expansion also helps in facilitating nasal breathing which in turn helps in improving facial growth, malocclusion and sleep.

The strength of the study is that expansion has been assessed at all 3 time points; i.e., T_0, T_1 and T_2 using a novel method of assessment. Very few studies have been done on semi-rapid expansion delivered by a removable appliance; so it fills the knowledge gap.

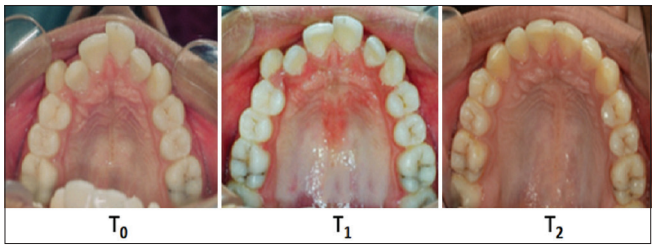

Figure 2: Comparison of Transverse Dimension at Pre-treatment (T_0), Post-expansion (T_1) and at debond (T_2)

In the clinical scenario treatments protocols in the transverse dimension are usually avoided due to complicated mechanics and chances of damage to the anchor teeth. The authors found this a simple, less laboratory intensive, more comfortable and hygienic method with the added benefit of being cost effective. There are many ways to expand and this could be one more method to add to the armamentarium of the orthodontist.

Limitations

This study could have been benefitted by the use of a control group.

Conclusion

Maxillary expansion using a semi rapid screw activation protocol and a removable appliance could be a simple and efficient alternative to other methods of expansion. The appliance and protocol were effective in producing transverse expansion by remodelling the palatal vault with minimal molar and alveolar tipping.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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