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Vertical, Sagittal and Transverse Effects of Semi Rapid Maxillary Expansion Protocol Using a Removable Expansion Appliance: A Cephalometric and Model Based Study

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ABSTRACT

Introduction*:* The aim of this study was to evaluate the vertical, sagittal and transverse effects of semi rapid maxillary expansion (SRME) in patients with transverse maxillary discrepancies using a modified removable expansion appliance assessed by lateral cephalograms and dental models.

Materials and Methods: The lateral cephalograms and dental models of 50 treated patients group were compared with those of 29 untreated control group at 3 different times: pretreatment (T_0), after expansion (T_1) and after fixed appliance therapy (T_2). The mean age for treated group was 13.8yrs (32 females; 18 males) and control group was 13.2yrs (15 males; 14 females). A total of 18 measurements (8 angular; 10 linear) were measured in vertical, sagittal and transverse planes at T_0, T_1 and T_2 stages. The T_0-T_1, T_1-T_2 and T_0-T_2 changes were compared statistically in treated group with respect to the corresponding untreated control group. The intra-group and inter-group comparisons were statistically analyzed using Wilcoxon signed rank test.

Results: In comparison to controlled group the following parameters in treated group showed a statistically significant change from T_0 to T_2. In vertical plane increase in ANS–Me and in sagittal plane decrease in angle ANB and OJ; increase in SNB and U1-SN was seen. In the transverse plane ICW, IPW, IMW, PMW showed net gain of 3.27, 5.06, 3.7 and 2.82mm respectively.

Conclusion: The results of present study suggest that the design and protocol followed in using SRME is effective for the correction of maxillary transverse discrepancies with acceptable vertical and sagittal control.

Key words: Semi Rapid Maxillary Expansion, Transverse Maxillary Deficiency, Sagittal and Vertical Effect, Lateral Cephalogram, Model study.

INTRODUCTION

Maxillary transverse deficiency is one of the most common conditions seen in the orthodontic office. The concept of maxillary expansion by opening of the mid palatal suture was introduced in the orthodontic literature by Angell in 1860. [1] Nearly 100 years after its introduction; the rapid maxillary expansion(RME) was popularized by the landmark works of Hass and became a routine procedure for the management of transverse deficiency in orthodontic offices. [2] On the basis of frequency of the activations, magnitude of the applied force, duration of the treatment, and patient age; maxillary expansion can either be rapid, semi rapid or slow maxillary expansion .[3-5] RME therapy is one of the most common orthopedic treatments for transverse maxillary deficiency. The rate of expansion in RME generally varies from 0.5mm and more per day over a period of 2-3 weeks. Twice-daily activation is usually recommended and the force of ~100N is generated at the mid-palatine suture. [6] RME not only produces expansion force at inter-maxillary sutures but also exerts greater force on various structures in the craniofacial complex. [7, 8] The long term evaluation of RME has also shown a tendency for relapse [8]. Slow Maxillary Expansion (SME) uses relatively lower orthopedic forces (5-20N) for longer time to accomplish similar amount of expansion. Half turn activation per week is usually recommended and this causes relatively lesser tissue resistance at the naso-maxillary complex. However the palatal expansion in SME is achieved after months instead of several weeks and also SME is said to have more of dental changes.[9] Hence to overcome the disadvantages of both RME and SME, a new method combining the effects of both namely, 'Semi Rapid Maxillary Expansion' (SRME) was recommended. [10] Several

SRME protocols have been described in the literature, with some authors using a fixed Hass or Hyrax appliance and few authors using a removable plate to deliver the force. [3, 10, 11] Though the effects of RME on skeletal, dental and nasal structures have been extensively studied by several researchers and well documented in the literature there are very few studies on the effect of a removable appliance and a semi rapid activation protocol to bring about the expansion. Removable expansion plates are not very popular these days even though they have many benefits like ease of insertion, minimum laboratory steps, better hygiene, fewer emergencies and ease of screw activation. This could be because they are associated with more dental movements, and longer time of treatment. One reason for this could be that the removable plates in the previous studies had a different design (2 retention clasps and a labial bow) and a different screw activation protocol. The authors felt that by improving the design of the plate and altering the activation protocol it would be possible to have a different result than that seen in previous studies. The present study was designed to assess the effect of maxillary expansion through SRME protocol and a removable appliance on the sagittal, vertical and transverse dimensions. There are very few studies on expansion using a removable plate as well as a semi rapid expansion protocol, so this study fills a gap in our knowledge.

MATERIAL AND METHOD

The study sample consisted of 50 consecutive patients treated with SRME using a removable expansion plate. Ethical clearance was taken (ECR/72/Indt./GJ/2013, Registration No. IORG0005424) and informed consent was taken from the patients and their parents.

Inclusive Criteria were:

- Medical history and examination negative for congenital maxillary malformation and related syndromes, severe skeletal asymmetry or dentofacial deformities requiring orthognathic surgery.
- Having lateral cephalogram as well as study models at Pretreatment (T_0), Post Expansion (T_1) and Post Fixed appliance (T_2). Time between T_0 and T_1 was 3.5 months (mean) and between T_1 and T_2 was 18 months (mean).
- Age between 12 to 15 years and cervical vertebrae maturation stage 3 or less at the time of taking lateral cephalogram (T_0).
- Selected patient needed palatal expansion for the correction of bilateral or unilateral crossbite, or maxillary tooth size arch length discrepancy with transpalatal width (Palatal Molar Width-PMW) less than 34mm. [12]

Appliance: All the patients were treated by the same operator using the same type of appliance. (**Fig. 1**). The appliance was a unique modification of the Schwarz expansion plate. Instead of 2 Adams clasps and a labial bow, the design was modified and 6 Adams clasps were given [on the 1st molars, 1st premolars or deciduous 1st molars and on lateral incisors]. The screw activation protocol was modified to a 45 degree turn (0.1 mm expansion) 6 days a week to deliver a constant low force. The plate was worn 24 hours a day, including meal times. Patients were advised to remove the plate during brushing and to maintain adequate oral hygiene. Post expansion, patients were put on fixed appliance (0.022x0.028" slot, MBT) for further treatment.

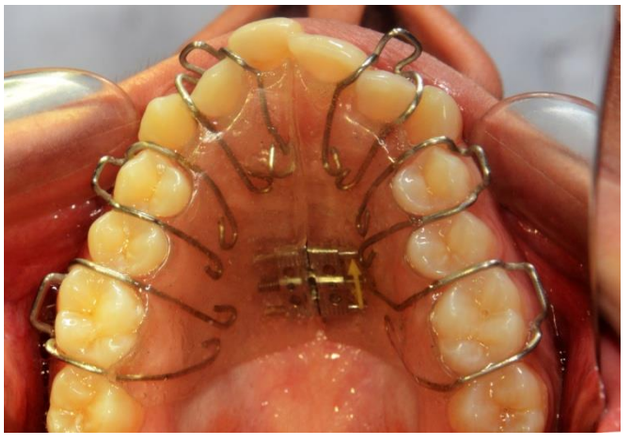

Figure (1): The removable expansion appliance used in this study.

The control group consisted of 29 subjects (14 males, 15 females, mean age 13.2 years) having minor irregularities. They were part of another study and were used with the permission of the authors.

The vertical and sagittal parameters were assessed on lateral cephalograms (Fig. 2) and the transverse parameters were assessed by measurements on study models (Fig. 3). (Table 1)

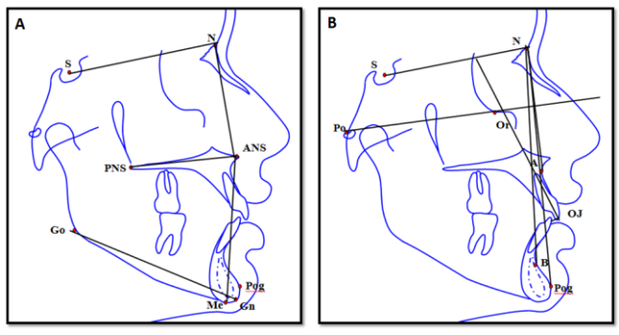

Figure (2): The vertical (A) and sagittal (B) parameters as assessed in the lateral cephalograms.

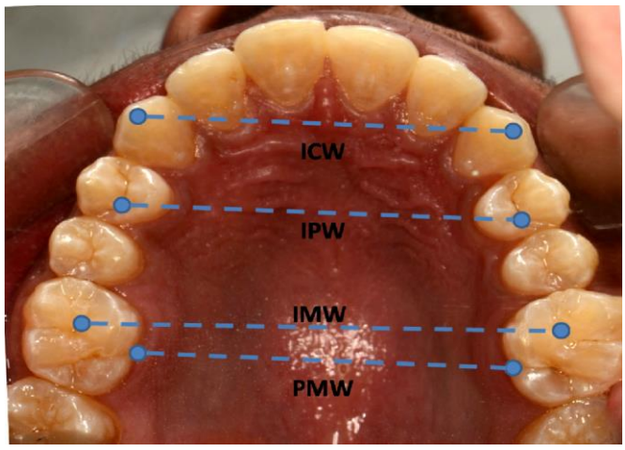

Figure (3): The transverse parameters as assessed on dental models.

Plane	Parameter	Description
Vertical	ANS-ME (mm)	Linear measurement from anterior nasal spine to menton
	N-ANS (mm)	Linear measurement from nasion to anterior nasal spine
	SN-Palatal Plane (°)	Angular measurement between sella nasion plane and palatal plane (ANS-PNS)
	Palatal Plane-GoGn (°)	Angular measurement between palatal plane (ANS- PNS) and mandibular plane (Go-Gn)
	SN-GoGn (°)	Angular measurement between sella- nasion plane and mandibular plane (Go-Gn)
Sagittal	SNA (°)	Angular measurement between sella-nasion and point A
	SNB (°)	Angular measurement between sella-nasion and point B
	ANB (°)	Angular measurement from point A- nasion and Point B
	FA (°)	Facial Angle as measured between FHP and N-Pog plane
	OJ (mm)	Horizontal linear measurement from labial surface of lower incisor to incisal edge of upper incisor (overjet)
	UI-SN (°)	Angular measurement between long axis of upper incisor and sella- nasion plane
Transverse	ICW (mm)	Inter-canine width as measured from upper right canine tip to upper left canine tip
	IPW (mm)	Inter-premolar width as measured from distal pit of upper right first premolar to upper left first premolar
	IMW (mm)	Inter-molar width as measured from central pit of upper right first molar to central pit of upper left first molar
	PMW (mm)	Transpalatal width as measured from the palatal groove of the maxillary right first molar to palatal groove of the maxillary left first molar

STATISTICAL ANALYSIS

The statistical analysis was performed using SPSS software version 16 and Microsoft Excel 2017. The normality of the parameters was determined using Shapiro Wilk test. Descriptive statistics were performed on cephalometric measurements and models at T_0, T_1 and T_2 for the treated group and control group. The following statistical comparisons were performed:

- Intra group comparison: Treated group T_0–T_1,T_1-T_2,T_0-T_2
- Intra group comparison: Control group T_0–T_1,T_1-T_2,T_0-T_2
- Inter group Comparison: treated group vs. control group at T_0, T_1 and T_2.

Intra-group and inter-group comparisons were done using Wilcoxon signed rank test. Significance was set at 0.05 for all statistical analyses.

ERROR STUDY

In order to evaluate measurement errors, re-tracing, landmark identification and re-measurement of randomly selected 20 lateral cephalograms was done by same evaluator after period of two weeks. The reliability of the measurements was obtained by using Intra class Correlation Coefficient [ICC] and Dahlberg's formula. No significant errors were present.

RESULTS

The treated group (n = 50) consisted of 32 girls and 18 boys and the control group (n = 29) consisted of 15 girls and 14 boys. The main characteristics of the samples were summarized in (**Table 2)**.

Intra-group comparison of parameters in all the 3 planes in the treated as well as control group are described in (**Tables 3,4)**. The evaluation of the changes of treated group in vertical plane showed statistically significance increase in ANS–Me from T_0 to T_2 (p value < 0.001) and statistically significant decrease in angle SN-GoGn from T_1 to T_2 (p value <0.001), in sagittal plane there was statistically significant decrease in angle SNB from T_0 to T_1 (p value < 0.05) , an increase from T_1 to T_2 (p value < 0.05) with a net increase from T_0 to T_2. (p value < 0.05). There was statistically significant increase in angle ANB from T_0 to T_1 (p value < 0.05) , an decrease from T_1 to T_2 (p value < 0.05) with a net decrease from T_0 to T_2. (p value < 0.05). Significance decrease in overjet (OJ) was seen from T_0 to T_2 (p value < 0.0001). In the transverse plane Inter-canine Width (ICW), Inter-premolar width (IPW), Inter-molar width (IMW), Palatal Molar Width (PMW) showed an statistically significant increase of 4.81mm, 5.61mm, 5.12mm and 4.61mm at T1 (p value < 0.0001), with a decrease of 1.53 (p value < 0.0001), 0.55(ns), 1.42 (p value < 0.0001), and 1.79(p value < 0.0001) at T_2 with a statistically significant net gain of 3.27, 5.06, 3.7 and 2.82mm respectively from T_0 to T_2 (p value < 0.0001). Differences for other skeletal and dental parameters were not significant.

*p<0.05 ; **p<0.001 ; ***p<0.0001

Table 2: Characteristics of treated group and control group

	Mean age ± SD (years)		
	T_0	T_1	T_2
Treated group	13.8 years ±1.43	14 years ± 0.5	15.8 years ± 1.6
Control group	13.2 years ± 1.3	13.6.years ± 0.3	15.5 years ± 1.2

DISCUSSION

There are many ways to expand the maxilla and the most frequently used appliance is the fixed Hass or Hyrax expander. Though there are many benefits of using a removable appliance for expansion; namely ease of insertion, fewer laboratory steps, ease of screw activation, better oral hygiene and cost efficiency, it is not very popular with the clinicians. There are very few articles on expansion using a removable screw plate and a semi rapid activation protocol. To the best of our knowledge this seems to be the only article where pre treatment (T_0), post expansion (T_1) and post fixed appliance (T_2) parameters using this protocol have been assessed. The purpose of this study was to analyze the effect of SRME using a removable plate on all the three planes viz., vertical, sagittal and transverse planes at three different time durations of T_0, T_1 and T_2. The effect on the vertical and sagittal planes was assessed through lateral cephalograms. PA views are commonly used to assess transverse changes, however superimposition of structures makes assessment difficult, patient is exposed to extra radiation and cost, and the clinically relevant data like changes in inter canine, inter pre molar and inter molar width is not possible to assess. Thus we decided to study changes in the transverse dimension using study models.

Table 3 : Intra-group comparison in the treated group.

Plane	Parameter	T_0-T_1			T_1-T_2			T_0-T_2		
		Mean	**S.E**	**Sig.**	**Mean**	**S.E**	**Sig.**	**Mean**	**S.E**	**Sig.**
Vertical	ANS-Me	-1.184	0.466	*	-0.711	0.529	ns	-1.895	0.529	**
	N-ANS	-0.289	0.341	ns	-0.605	0.363	ns	-0.895	0.428	ns
	SN-Palatal Plane	-.474	0.244	ns	0.816	0.311	*	0.342	0.230	ns
	Palatal Plane-GoGn	-0.158	0.371	ns	0.658	0.512	ns	0.500	0.441	ns
	SN-GoGn	-.632	0.361	ns	1.474	0.418	**	0.842	0.409	ns
Sagittal	SNA	0.342	0.502	ns	-0.816	0.469	ns	-0.474	0.657	ns
	SNB	0.988	0.502	*	-3.145	0.44	*	-2.157	0.55	*
	ANB	-0.651	0.648	*	2.33	0.324	*	1.679	0.428	*
	FA	0.474	0.783	ns	0.921	0.945	ns	-0.447	0.801	ns
	OJ	0.839	0.247	**	0.424	0.25	ns	1.263	0.27	***
	UI-SN	-0.342	0.734	ns	-1.658	1.202	ns	-2.000	1.212	ns
Transverse	ICW	-4.815	0.34	***	1.538	0.316	***	-3.277	0.385	***
	IPW	-5.616	0.477	***	0.552	0.4	ns	-5.064	0.427	***
	IMW	-5.129	0.305	***	1.42	0.424	***	-3.7	0.348	***
	PMW	-4.614	0.264	***	1.795	0.345	***	-2.820	0.318	***

In the vertical direction, there was an overall increase in the facial height, contributed by a significant increase in ANS-Me. Post expansion we found a non significant increase in angle SN-GoGn which decreased after the fixed appliance treatment to values similar to those in the control group. This is in contrast to other studies which reported an increase in vertical height and an increase in the mandibular plane angle after treatment, [13-17] but in agreement with other authors who have noted that the increase in vertical height of the ramus during growth could have led to the decrease in the SN-GoGn angle without affecting the anterior vertical dimension. [18,19]

In the sagittal direction, this study found significant differences in angle SNB, and highly significant difference in angle ANB and overjet when compared to the control group at T_2. This shows that maxilla is stable during SRME, neither moving forward or backward, however the mandible moves forward thus decreasing the overjet. This repositioning of the mandible has also been noted by other authors who have noticed the improvement in Class II malocclusion towards Class I after expansion treatment. [20,21]

In the transverse direction there was a significant increase in width at canine, premolar and molar levels at T_1 followed by a decrease at T_2, with a net overall increase from T_0 to T_2. A highly significant difference was observed at the premolar level followed by the molar level, when compared to the control group. This suggests that the maximum expansion in treatment groups occurred at the premolar region even though significant

differences were observed at canine and at molar regions. These findings are consistent with other studies where it was observed that the maxillary inter molar and maxillary inter-canine widths increased as a result of both expansion plates and quad helix appliances. [3,22]

Table 4: Intra-group comparison in control group.

Plane	Parameter	T_0-T_1			T_1-T_2			T_0-T_2		
		Mean	**S.E**	**Sig.**	**Mean**	**S.E**	**Sig.**	**Mean**	**S.E**	**Sig.**
Vertical	ANS-Me	0.433	1.455	ns	-1.933	1.606	ns	-1.5	2.096	ns
	N-ANS	-0.533	0.973	**	-0.017	0.999	ns	-0.55	0.820	**
	SN-Palatal Plane	-0.5	0.682	***	0.250	0.341	***	-0.250	0.341	***
	Palatal Plane-GoGn	-0.4	1.610	ns	1.266	0.805	ns	0.866	0.805	ns
	SN-GoGn	-0.66	1.689	**	1.35	0.967	**	0.69	0.844	**
Sagittal	SNA	-0.067	1.172	***	-0.867	0.586	***	-0.934	0.586	***
	SNB	-0.066	1.478	ns	-0.717	0.739	ns	-0.784	0.739	ns
	ANB	0	1.978	ns	-0.164	0.989	ns	-0.164	0.989	ns
	FA	0.066	1.337	ns	-0.07	0.785	ns	-0.634	1.456	ns
	OJ	0.003	0.450	ns	0.198	0.454	ns	0.201	0.320	ns
	UI-SN	0.06	0.944	ns	-1.13	2.572	ns	-1.07	2.412	ns
Transverse	ICW	-0.012	0.996	ns	0.11	0.489	ns	0.008	0.498	ns
	IPMW	0.55	0.624	ns	0.75	0.493	ns	1.3	0.491	ns
	IMW	-0.03	0.814	*	-0.77	0.424	**	-0.8	0.476	ns
	PMW	-0.01	0.607	ns	-0.06	0.304	ns	-0.07	0.304	Ns

***p<0.05 ; **p<0.001 ; ***p<0.0001**

This favorable outcome in the transverse dimension probably could be ascribed to the different appliance design and protocols followed in this study. The design of the appliance is such that the 6 Adams clasps distributed the forces at anterior and posterior part of palate while the slower SRME protocol allowed the tissues to remodel and adapt, thereby allowing the expansion to remain stable even after fixed appliance treatment.

Limitations and strengths of this study:

Limitations:

1) Sample collected from the author's clinic was predominantly female .While it represents a realistic clinical scenario applicable to clinical practice, this gender distribution should be considered carefully in interpreting our findings.

2) Long term post retention research could be considered.

Strengths:

1) Very few articles have studied changes brought about by an expansion appliance at all three time periods T_0,T_1 & T_2 and in all 3 directions (transverse, vertical, sagittal) and with high sample size.

2) Also the use of the removable expansion plate with a modified expansion protocol has not been widely discussed in literature.

CONCLUSION

The results of present study suggest that the design and protocol followed in using SRME brought about by a removable appliance is effective for the correction of maxillary transverse discrepancies with acceptable vertical and sagittal control. Maximum effect was obtained in the transverse plane followed by sagittal and vertical plane.

Conflict of interest: None

Acknowledgement: None

Funding: None

Comparison between treated group and control group showed statistically significant difference in SNB (p value <0.001), ANB (p value <0.0001), OJ (p value <0.0001), ICW (p value <0.001), IPW (p value <0.001), IMW(p value <0.05), PMW (p value <0.05) at T0 and in ANS-Me (p value <0.05), SNB (p value <0.001), ANB (p value <0.0001), OJ (p value <0.0001) , ICW(p value <0.05), IPW(p value <0.001), IMW(p value <0.0001) and PMW (p value <0.0001) at T1. At T2 ANS-Me (p value <0.05), SNB (p value <0.001), ANB (p value <0.0001),

OJ (p value <0.0001), UI –SN (p value < 0.05), ICW (p <0.05), IPW (p value <0.0001), IMW (p value <0.05) and PMW (p value <0.001) showed significance difference. The differences for other skeletal and dental parameters were not significant (Table 5).

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Table 5: Table showing the comparison between treatment group and control group at three timelines.

Parameter	Time	Treatment Group		Control Group		P Value
		Mean	(S.D)	Mean	(S.D)	
ANS-Me	T_O	60.78	(5.42)	59.86	(4.01)	ns
	T_1	61.97	(5.44)	59.43	(4.02)	*
	T_2	62.68	(5.82)	61.36	(4.02)	*
N-ANS	T_O	47.13	(3.9)	47.16	(3.65)	ns
	T_1	47.42	(3.61)	47.63	(3.69)	ns
	T_2	48.02	(3.68)	47.65	(3.69)	ns
SN-Palatal Plane	T_O	5.42	(2.53)	5.96	(2.52)	ns
	T_1	5.89	(2.96)	6.46	(2.41)	ns
	T_2	5.07	(2.85)	6.21	(2.45)	ns
Palatal Plane-GoGn	T_0	21.86	(4.42)	20.36	(3.48)	ns
	T_1	22.02	(4.55)	20.7	(3.79)	ns
	T_2	21.36	(3.98)	19.5	(3.37)	**ns**
SN-GoGN	T_O	27.28	(4.44)	26.4	(4.09)	ns
	T_1	27.92	(4.64)	27.06	(4.12)	ns
	T_2	26.44	(4.01)	25.71	(3.85)	ns
SNA	T_O	83.6	(4.89)	82.36	(2.26)	ns
	T_1	83.26	(3.94)	82.43	(2.26)	ns
	T_2	84.07	(4.35)	83.31	(2.28)	ns
SNB	T_O	78.00	(3.97)	81.4	(2.19)	**
	T_1	77.012	(4.17)	81.46	(2.16)	**
	T_2	80.15	(4.23)	82.18	(2.67)	*
ANB	T_O	5.600	(3.1)	0.96	(1.69)	***
	T_1	6.25	(2.25)	0.97	(2.02)	***
	T_2	3.92	(2.4)	1.13	(1.83)	***
FA	T_O	93.05	(5.16)	92.46	(2.73)	ns
	T_1	92.57	(5.98)	92.4	(2.74)	ns
	T_2	93.5	(6.21)	93.1	(2.46)	ns
OJ	T_O	4.56	(1.69)	2.316	(1.11)	***
	T_1	3.72	(1.39)	2.313	(1.2)	***
	T_2	3.3	(1.03)	2.115	(1.06)	***
UISN	T_O	109.28	(7.69)	106.26	(5.64)	ns
	T_1	109.63	(9.44)	106.2	(5.59)	ns
	T_2	111.28	(7.09)	107.3	(5.22)	*
ICW	T_O	33.05	(3.75)	35.5	(2.68)	**
	T_1	37.87	(3.81)	35.61	(2.80)	*
	T_2	36.33	(3.72)	35.5	(2.76)	*
IPW	T_O	34.89	(3.83)	37.85	(2.72)	**
	T_1	40.5	(3.99)	37.3	(3.35)	**
	T_2	39.95	(3.56)	36.55	(2.64)	***
IMW	T_O	45.06	(4)	47.12	(2.37)	*
	T_1	50.18	(3.94)	47.15	(2.27)	***
	T_2	48.76	(4.08)	47.92	(2.28)	*
PMW	T_O	34.23	(3.79)	35.59	(2.29)	*
	T_1	38.84	(3.75)	35.6	(2.21)	***
	T_2	37.05	(3.88)	35.66	(2.28)	**

***p<0.05 ; **p<0.001; ***p<0.0001**

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