Original Article

Micro-osteoperforation effectiveness on tooth movement rate and impact on oral health related quality of life: *A randomized clinical trial*

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ABSTRACT

Objectives: To investigate the effect of micro-osteoperforation (MOP) on the rate of tooth movement (RTM), space closure duration, and oral health–related quality of life (OHRQoL) during completion of anterior retraction in patients undergoing combined orthodontic-surgical treatment after premolar extraction and decompensation with sliding mechanics.

Materials and Methods: Twenty-four participants with indications for premolar extractions were randomly allocated to treatment with conventional sliding mechanics (control group; CG) or with to treatment in which three MOPs were performed every activation (experimental group; EG). Dental impressions were taken monthly until space closure was completed and dental casts were converted to three-dimensional models. After the anterior retraction procedure, Oral Health Impact Profile (OHIP-14) questionnaires were filled out at 4 and 72 hours.

Results: Eighteen patients (7 men and 11 women) remained in the trial until space closure was completed (mean follow-up period = 247 days). For full space closure RTM, no significant difference ($P = .492$) was found between groups (0.614 mm/month for the CG; 0.672 mm/month for the EG). The RTM for different time points, groups, time frames and their interaction were statistically different ($P < .05$). In multiple correlation analysis, the RTM significantly decreased over time for both groups ($P < .05$). The OHRQoL scores were significantly higher (worse) for the EG. The psychological, physical and social disabilities, and handicap domains displayed significant differences between the two groups.

Conclusion: Use of MOPs did not change the full space closure RTM, while it had a negative impact on OHRQoL. (*Angle Orthod.* 2020;90:640–647.)

KEY WORDS: Tooth movement; Quality of life; Orthodontics; Digital imaging

INTRODUCTION

Shortening the duration of treatment has long been a goal in the specialty of orthodontics.[1] In an attempt to achieve this, manipulating the biological response to force application in order to accelerate tooth movement has been a topic in orthodontics. Clinicians have recently introduced several surgical techniques[2,3] to improve or facilitate the rate of tooth movement (RTM) and to reduce iatrogenic damage caused by the long-term wear of fixed appliances.[4,5] Many authors have reported a shortened time for orthodontic treatment by using those techniques.[6–8]

The development of minimally invasive techniques, such as micro-osteoperforations (MOPs), has made accelerated orthodontics more acceptable.[9,10] Whereas some studies about the effect of MOPs on RTM showed positive results,[9,11–13] other studies have shown no significant clinical differences.[14–17] Recently, two systematic reviews about the effectiveness of MOPs had opposite conclusions.[18,19]

Even with good acceptance rates, the prospect of an extra surgical procedure could increase apprehensive-

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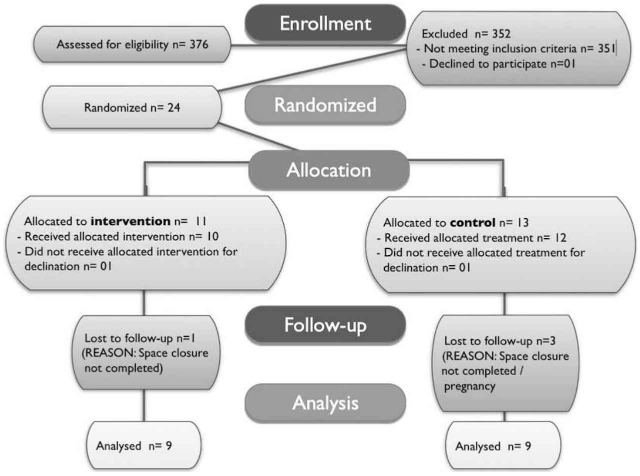

Figure 1. Consort flow chart.

ness, affecting subjective and qualitative aspects of life.[15] Oral health–related quality of life (OHRQoL) instruments are widely useful in orthodontic populations[20]; they are reliable and efficient for evaluating quality of life and the impact of many dental treatments.[21,22]

Based on the conflicting results regarding the effectiveness of MOPs in accelerating tooth movement and the lack of scientific information about the impact of MOPs on the duration of treatment, this study investigated the RTM during space closure and patients' perceptions using the Oral Health Impact Profile (OHIP-14).[23] The primary purpose was to evaluate and compare the rate of tooth movement and time needed for extraction space closure, with and without MOPs, in patients undergoing surgical orthodontic treatment. The secondary outcome was to evaluate how MOPs affect OHRQoL.

MATERIALS AND METHODS

Trial Design

The patients participated in a two-arm parallel randomized clinical trial with a balanced allocation ratio (1:1). The study was approved by the Research Ethics Committee of the University of Sao Paulo, School of Dentistry, Sao Paulo, Brazil (2.291.627) and was registered at www.clinicaltrials.gov (NCT02416297).

Participants

We assessed 376 consecutive patients for eligibility in the trial at the Ortho-Surgical Clinic at the University of Sao Paulo School of Dentistry, Sao Paulo, between February and September 2015 (Figure 1). The study sample consisted of 22 patients who were selected for orthodontic-surgical treatment and premolar extraction performed for decompensation. Assessment of OHRQoL was done after the initiation of space closure, and the RTM was assessed after total space closure.

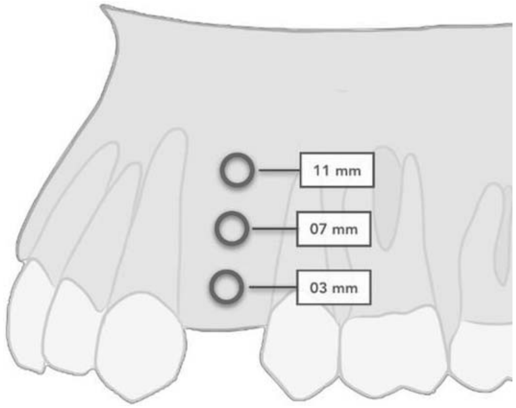

Figure 2. Micro-osteoperforation protocol.

The inclusion criteria were maxillomandibular discrepancy indicating a need for orthognathic surgery, no previous dental extractions, the need for extraction of the upper or lower first premolars as part of the orthodontic treatment plan, good oral and general health, nonsmoker, and no use of systemic corticosteroids or bisphosphonates.

Interventions

The participants were randomly allocated to one of two groups: (1) control group (CG), in which anterior retraction was performed using implant-assisted sliding mechanics with self-ligating brackets (Orthometric, Marilia, Brazil), and (2) experimental group (EG), in which MOPs were performed with Excellerator RT (Propel Orthodontics, Ossining, NY).

For retraction, 10-mm-long miniscrews (Morelli, Sorocaba, Brazil) were loaded between the first and second molars bilaterally. Anterior retraction was initiated 28 days after insertion of 0.019″ × 0.025″ stainless steel archwires. A 9-mm NiTi closed coil spring (Orthometric) was applied from the miniscrew to the hook placed distal to the canines using 200 g force on each side. In an effort to collect data without interference that could affect the primary outcome, occlusal composites were constructed before the trial began to allow for reliable assessment.

The EG participants received three vertical MOPs in the space midway between the canine and second premolar, 6 mm in depth (Figure 2). The MOPs were performed during every activation session by the same operator, who combined visualization and palpation of the bone and root bulge to determine an appropriate and safe space for the perforations. The average number of acceleration procedure sessions was seven (range = 5–8).

Rate of Tooth Movement

Alginate impressions were taken at each activation session until complete space closure was achieved. A pre-retraction model (T0) was made 28 days after the insertion of 0.019″ × 0.025″ stainless steel archwires. Plaster dental models were digitally converted (XCAD 3D Scanner, True Image Belo Horizonte, Brazil, and Maestro 3D OrthoStudio, AGE Solutions, Pisa, Italy) by the same operator. Three-dimensional (3D) linear measurement assessment was obtained using the Q3DC tool (SlicerCMF3-1 4.5.0, http://www.slicer.org). The extraction space was measured on the surface models between two landmarks: the most distal point on the canine and the most mesial point on the second premolar. For RTM calculations, the means for both the left and right sides were used.

Oral Health–Related Quality of Life

For this assessment, the differences between groups for immediate (IA) and follow-up (LA) periods were analyzed. Participants were asked to complete an electronic OHIP-14 questionnaire 4 hours after the initial activation appointment (Q1) and 72 hours after the activation appointment (Q2) to investigate the postoperative comfort level.

Sample-Size Calculation

Sample-size calculation was performed based on the first published study about MOPs,[9] in which the mean rate for canine retraction in conventional orthodontic treatment was 0.60 mm/month (SD = 0.36 mm). Hypothesizing that MOPs would accelerate the rate around 0.4 mm, with 80% power at $P = .05$, the sample-size analysis indicated 13 participants per group.

Randomization

Randomization was performed with number sequences generated using the Random function in Excel with a 1:1 allocation ratio. The list of participants was randomly rearranged and divided into two groups, with the first half assigned to the CG and the second to the EG. To prevent selection bias, before the randomization procedure, participants' names were converted into letters and numbers by a different investigator to ensure allocation concealment.

Blinding

Blinding was not possible because of the type of intervention. To ensure blinding feasibility, data collectors and outcome assessors were blinded for analysis.

Table 1. Cephalometric Baseline Characteristics of the Participants

	Control Group (N = 9)	Experimental Group (N = 9)	*P* Value
SNA			.391
Mean ± SD	82.02 ± 2.83	83.24 ± 3.01	
Minimum; maximum	78.00; 87.52	77.53; 86.48	
SNB			.913
Mean ± SD	81.18 ± 8.27	81.56 ± 6.12	
Minimum; maximum	65.37; 91.09	75.44; 88.44	
ANB			.294
Mean ± SD	−1.37 ± 5.07	1.63 ± 6.60	
Minimum; maximum	−9.20; 5.84	−6.80; 9.40	
NS.GoGn			.84
Mean ± SD	37.13 ± 5.97	37.79 ± 7.62	
Minimum; maximum	28.52; 44.79	29.91; 48.76	
NS.Gn			.185
Mean ± SD	64.54 ± 4.10	70.36 ± 6.96	
Minimum; maximum	58.88; 68.42	62.76; 75.91	
1.NS			.39
Mean ± SD	118.96 ± 8.64	114.39 ± 4.76	
Minimum; maximum	111.80; 131.49	110.26; 118.51	
IMPA			.334
Mean ± SD	86.84 ± 17.22	96.37 ± 22.98	
Minimum; maximum	69.99; 110.96	67.78; 126.35	

Statistical Analysis

Descriptive statistics were used on demographic, initial space, rate of space closure, time for total space closure, and cephalometric measurements and were tested for normality with the Kolmogorov-Smirnov test. For intergroup comparisons, an unpaired *t*-test was applied since data were normal. To ensure the reliability of results due to a relatively small sample size, statistical power was tested for all variables. All tests were performed at $P < .05$.

RESULTS

For the primary outcome, 18 participants were allocated and completed the study, providing 70% of power to detect 0.4 mm of difference. Cephalometric characteristics showed no statistical difference between groups at baseline (Table 1). Assessment of 3D linear measurements obtained using the Q3DC tool showed a high intraclass correlation coefficient value (>0.99), in agreement with other 3D assessments.[24,25] A Bland-Altman plot showed high agreement for the 3D measurements (Figure 3).

Table 2 shows data regarding tooth movement, and age and gender distribution. No statistically significant difference was found in RTM between upper and lower dentition ($P = .138$). Analysis of covariance was performed for comparing closing time, testing the baseline space variable, and, for monthly closing rate comparison, testing the age variable. No statistical differences were found.

Figure 3. Bland-Altman plot for measurement agreement.

This study was the first trial to show complete space closure data with MOPs. In the comparison between RTM average for each group at each evaluated time, the EG showed higher values than the CG from session 1 through session 6; only by session 9 were the results similar. Both groups showed a reduction in the values over the sessions (Figure 4). The RTM average was significantly different between groups over the sessions ($P = .027$) (Table 3). Therefore, multiple comparisons were tested (Table 4).

For the secondary outcome, 22 patients completed the electronic questionnaire. Baseline characteristics for the groups were similar. The EG showed the most severe impact on OHRQoL, according to the OHIP-14A (Table 5). Regarding the OHIP-14A categories, the CG was ranked as category 1, and the EG was ranked as category 2 in both assessments. Results of the two-way analysis of variance at IA and LA showed scores significantly higher in the EG. The OHIP-14 Seven domains were similarly affected by the MOPs (Table 5).

DISCUSSION

This randomized controlled trial was designed to evaluate RTM using MOPs, and no statistically significant difference was found, similar to previous investigations,[14,16,17] which showed monthly RTMs that were similar to the current results.

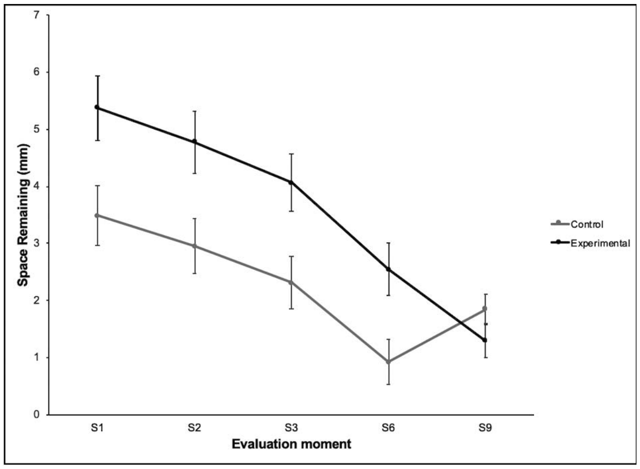

Figure 4. Comparison of tooth movement between groups and time points.

In contrast, Alikhani et al.[9] and Feizbakhsh et al.[11] found the greatest increase in RTM with MOPs but used different numbers of holes, force applied, and duration for their studies. Sivarajan et al.[15] affirmed that although the increase in canine retraction rate was statistically significant, it was clinically meaningless; thus, to suggest that a shorter treatment time would be highly speculative.

Although enhanced rates (30%) for anterior retraction were found after use of the originally recommended device,[13] the current results showed no enhanced rate using the same equipment; this was in agreement with and reported the same average rate as a previous study using regular Temporary Anchorage Devices (TADs).[14] It does not make

Table 2. Age, Gender, and Tooth Movement Data Described by Groups[a]

	Control Group (N = 9)	Experimental Group (N = 9)	Total (N = 18)	*P* Value	Observed Power
Age (y)				.014	0.863
Mean ± SD	20.4 ± 2.6	27.8 ± 6.3	25.1 ± 6		
Minimum; maximum	18; 24	18; 36	18; 36		
Gender, No. (%)				>.999[b]	0.072
Female	5 (55.6%)	6 (66.7%)	11 (61.1%)		
Male	4 (44.4%)	3 (33.3%)	7 (38.9%)		
Baseline space (mm)				.024	0.638
Mean ± SD	3.49 ± 1.7	5.38 ± 1.55	4.43 ± 1.85		
Minimum; maximum	2.12; 7.46	3.16; 7.37	2.12; 7.46		
Monthly closing rate (mm)				.546	0.101
Mean ± SD	0.614 ± 0.173	0.672 ± 0.175	0.643 ± 0.171		
Minimum; maximum	0.341; 0.829	0.432; 0.887	0.341; 0.887		
Closing time (d)				.04	0.804
Mean ± SD	205.3 ± 72.7	289.3 ± 42	247.3 ± 72		
Minimum; maximum	112; 308	224; 364	112; 364		

[a] Student *t*-test.

[b] Fisher exact test.

Table 3. Space Remaining (Average Tooth Movement Values) Between the Experimental (Micro-osteoperforation) Group and the Control Group Over Anterior Retraction Activation Session From Baseline to Session 9 and Statistical Results[a]

	Control Group (N = 9)	Experimental Group (N = 9)	*P* Value Groups	*P* Value Timeframes	*P* Value Interaction
Space remaining (session [S] each 28 d)			.013	<.001	.027
S1					
Mean ± SD	3.5 ± 1.7	5.4 ± 1.5			
Minimum; maximum	2.1; 7.5	3.2; 7.4			
S2					
Mean ± SD	3 ± 1.7	4.8 ± 1.5			
Minimum; maximum	1.7; 6.9	2.4; 6.7			
S3					
Mean ± SD	2.3 ± 1.5	4.1 ± 1.4			
Minimum; maximum	0.7; 5.8	2.1; 6.3			
S6					
Mean ± SD	0.9 ± 1.3	2.6 ± 1.2			
Minimum; maximum	0; 3.2	1.2; 4.8			
S9					
Mean ± SD	1.8 ± 0.5	1.3 ± 0.7			
Minimum; maximum	1.4; 2.4	0; 2.3			

[a] GEE (Generalized estimating equation) with normal distribution and identify link function.

sense to believe bone and biological processes would respond differently to different devices if depth and MOP design were similarly performed. Biological response events should be the same regardless of the technique. In this study, the rate was the same for both groups, showing that MOPs were inefficient at accelerating tooth movement. The results were in agreement with those of previously established tooth movement rates[26] and control group results for many MOP studies.[9,13,14]

The regional acceleratory phenomenon (RAP) was described to remain *in situ* for 3 to 4 months after surgical trauma[2]. In this study, the MOPs were performed at every activation session for EG. Thus, MOPs could be considered insufficient to cause RAP and accelerate tooth movement during anterior retrac-

Table 4. Bonferroni Multiple Comparisons for Average Tooth Movement Values (Space Remaining) Between Groups and Activation Sessions

Group/Time Frame (Session [S])	Time Frame Comparisons	Mean Difference	Standard Error	Degrees of Freedom	*P* Value	95% Confidence Interval	
						Lower	Upper
Control group	S1 vs S2	0.54	0.13	1	.002	0.11	0.97
	S1 vs S3	1.18	0.19	1	<.001	0.57	1.79
	S1 vs S6	2.75	0.23	1	<.001	2.00	3.50
	S1 vs S9	3.31	0.32	1	<.001	2.26	4.35
	S2 vs S3	0.64	0.13	1	<.001	0.21	1.07
	S2 vs S6	2.22	0.19	1	<.001	1.59	2.84
	S2 vs S9	2.77	0.3	1	<.001	1.80	3.73
	S3 vs S6	1.57	0.14	1	<.001	1.12	2.03
	S3 vs S9	2.13	0.27	1	<.001	1.26	2.99
	S6 vs S9	0.55	0.23	1	.709	–0.19	1.30
Experimental group	S1 vs S2	0.6	0.13	1	<.001	0.17	1.03
	S1 vs S3	1.31	0.19	1	<.001	0.71	1.92
	S1 vs S6	2.83	0.23	1	<.001	2.09	3.56
	S1 vs S9	4.25	0.26	1	<.001	3.40	5.11
	S2 vs S3	0.71	0.13	1	<.001	0.28	1.14
	S2 vs S6	2.22	0.19	1	<.001	1.62	2.83
	S2 vs S9	3.65	0.23	1	<.001	2.90	4.40
	S3 vs S6	1.51	0.13	1	<.001	1.08	1.95
	S3 vs S9	2.94	0.19	1	<.001	2.31	3.56
	S6 vs S9	1.42	0.14	1	<.001	0.97	1.88
S1	Control vs Experimental	–1.89	0.68	1	.261	–4.12	0.34
S2	Control vs Experimental	–1.82	0.68	1	.344	–4.05	0.41
S3	Control vs Experimental	–1.75	0.68	1	.466	–3.98	0.48
S6	Control vs Experimental	–1.81	0.69	1	.365	–4.05	0.42
S9	Control vs Experimental	–0.94	0.71	1	>.999	–3.26	1.38

Table 5. Mean, Standard Deviation, Median, and Analysis of Variance According to Groups, Assessments, and Their Interactions[a]

	Control (N=12)		Experimental (N=10)		*P* Value Groups	*P* Value Time Frames	*P* Value Interaction
	Q1[b]	Q2[c]	Q1	Q2			
OHIP-14					.003	<.001	.004
Mean ± SD	10.42 ± 5.96	7.25 ± 6.90	23.30 ± 11.79	23.20 ± 15.96			
Functional limitation					.265	.418	.096
Mean ± SD	0.58 ± 1.73	0.33 ± 1.15	0.80 ± 0.92	1.50 ± 2.12			
Pain					.228	.080	.080
Mean ± SD	4.67 ± 2.31	3.42 ± 2.23	5.20 ± 2.15	0.70 ± 1.89			
Psychological discomfort					.001	.012	.035
Mean ± SD	1.00 ± 1.28	0.83 ± 1.40	4.90 ± 2.38	3.30 ± 2.79			
Physical disability					.004	.358	.218
Mean ± SD	1.83 ± 1.53	1.17 ± 1.75	4.40 ± 2.80	4.50 ± 2.88			
Psychological disability					<.001	.679	.049
Mean ± SD	0.50 ± 0.67	0.17 ± 0.39	2.20 ± 1.32	2.70 ± 2.16			
Social disability					.013	.597	.597
Mean ± SD	0.92 ± 1.44	0.92 ± 1.16	2.70 ± 1.89	3.00 ± 2.54			
Handicap					.005	.333	.516
Mean ± SD	0.92 ± 1.38	0.42 ± 0.90	3.10 ± 2.38	3.00 ± 2.62			

[a] OHIP-14 indicates Oral Health Impact Profile.
[b] 4 hours after initial activation.
[c] 72 hours after initial activation.

tion. However, the same design and number were utilized in previous MOP studies.[9,12–15,26] Therefore, more studies should be undertaken to test different MOP designs and numbers to determine conclusively if this accelerated technique can be effective, which was not clear based on the existing studies.

Based on the regional acceleratory phenomenon (RAP), accelerated tooth movement techniques were indicated for decreasing orthodontic treatment time. With optimistic effects for short-term evaluation, several authors[6,7,9,10] found that the MOPs method reduced overall orthodontic treatment time. This was the first study to show data for space closure completion assessing MOPs as an acceleratory technique. No statistically significant differences were found between groups regarding overall space closure.

The decrease in RTM over time in both groups confirmed a biological resistance after applying an orthodontic force. In this study, even using MOPs monthly as an acceleratory technique, it was unable to change the biological pattern of tooth movement. In agreement with this finding, several authors[11,14,17] found decreasing rates of tooth movement for each consecutive month evaluated.

To confirm the hypothesis that MOPs are an efficient and biologically active clinical procedure, their effect needs to be greater than that of other orthodontic procedures since orthodontic treatment already causes RAP. Studies have shown unsatisfactory results for clinical implications, an inability to produce faster tooth movement, or inconsistent overall treatment time reduction, probably caused by the small effect on biological response.

Achieving an adequate sample size was the greatest challenge in this trial. Besides enrollment difficulties, the participants were patients referred for tooth extraction and decompensation in preparation for orthognathic surgery, the smallest orthodontic patient population. Although this study had a small sample size, the standard deviation for the primary outcome (0.17 mm) was less than that found in other MOP studies.[11–15] This showed the lowest variability among all previous studies that evaluated RTM. The low variability improved the statistical power and ability to draw conclusions.

The OHRQoL was significantly affected by malocclusion and orthodontic treatment.[27] In this study, the IA and LA were chosen to examine changes only due to the MOP procedure, excluding possible changes in OHRQoL caused by malocclusion, orthodontic treatment, and dental decompensation, suggested as the most stressful period for this type of orthodontic treatment.[28] As MOP is a new acceleratory technique, it was crucial to understand patient perceptions and the interrelationships with psychological factors above and beyond the level of pain alone.[29]

Despite both groups being ranked as not at all affected for OHRQoL, the EG had statistically significant differences for severity compared with the CG. This indicated that the EG experienced more impact on quality of life. Thus, patients and clinicians considering accelerated orthodontics should be aware of the recovery period and the possibility for an unfavorable effect on quality of life after the procedure.[30] Whereas the EG experienced local anesthesia and three MOPs in each right and left buccal gingival tissue area, the domains with statistically significant differences was not pain but psychological discomfort and psychological disability, in agreement with other studies on orthodontic treatment.[31] These domains had the most different scores over the time frame of OHIP-14 and were the main factors regulating quality of life.[32]

On the other hand, pain did not show statistically significant differences between groups, times, or the interaction. This was in agreement with other MOP studies,[9,14] which found the same results for pain within groups, suggesting a slight inflammatory response for MOPs compared with regular orthodontic activations. Other authors have found differences in pain for MOP groups.[13,15] Although pain was not a limitation for MOPs, psychological discomfort and psychological disability were higher for the intervention group, which confirmed the impact of surgical procedures on patients' lives. Nevertheless, appraisal of patients' psychological status and their psychological concerns should be the priority over oral biologic issues.[32]

Limitations

Limitations could be characterized as: sample size, dropout rate, multiple sessions for data collection, and the absence of an OHIP-14 baseline questionnaire.

CONCLUSIONS

- Three MOPs did not accelerate overall tooth movement during anterior retraction using sliding mechanics.
- MOPs had a greater effect on OHRQoL immediately after the MOP procedure and after 3 days and mostly affected the psychological discomfort and "psychological disability domains.

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