

Comparison of orthodontic space closure using micro-osteoperforation and passive self-ligating appliances or conventional fixed appliances: *A randomized controlled trial*

Rashmi Mittal^a; Sonal Attri^a; Puneet Batra^b; Saurabh Sonar^c; Karan Sharma^d; Sreevatsan Raghavan^e

ABSTRACT

Objectives: To examine the effect of micro-osteoperforation (MOP) on the space closure rate using passive self-ligating or conventional brackets.

Materials and Methods: This was a two-arm parallel randomized controlled trial undertaken at the outpatient department of a dental college. There were 60 participants (30 women and 30 men) who fulfilled the inclusion criteria. Both the study and control groups were subjected to MOPs throughout the period of space closure. MOPs were repeated every 28 days. The experimental group (mean age 19.5 ± 1.66 years) was bonded with passive self-ligating brackets while the control group (mean age 19.9 ± 1.13 years) was bonded with conventional brackets. Both groups were examined and compared for rate of space closure. An evaluation was conducted for both groups until the entire extraction space was closed and confirmed by evaluation of a tight contact between the canine and the second premolar using a piece of dental floss.

Results: Before the initiation of retraction, all initial criteria were similar between the two groups ($P > .05$). No difference was observed between the two groups in the rate of space closure ($P > .05$).

Conclusions: MOP in conjunction with passive self-ligation does not increase the rate of orthodontic space closure when compared with MOP used with conventional brackets. (*Angle Orthod.* 2020;90:634–639.)

KEY WORDS: Micro-osteoperforations; Space closure; Passive self-ligating appliances

^a Postgraduate student, Department of Orthodontics and Dentofacial Orthopedics, Institute of Dental Sciences and Technologies, Modinagar, UP, India.

^b Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Institute of Dental Sciences and Technologies, Modinagar, UP, India.

^c Professor, Department of Orthodontics and Dentofacial Orthopedics, Institute of Dental Sciences and Technologies, Modinagar, UP, India.

^d Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, Institute of Dental Sciences and Technologies, Modinagar, UP, India.

^e Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics, Institute of Dental Sciences and Technologies, Modinagar, UP, India.

Corresponding author: Dr Karan Sharma, Department of Orthodontics and Dentofacial Orthopedics, Institute of Dental Sciences and Technologies, Modinagar, UP, India (e-mail: dr.sharmakaran@gmail.com)

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INTRODUCTION

Closure of the extraction space in orthodontics is achieved by employing either low- or high (sliding)–friction mechanics. Closing loops and a clear understanding of biomechanics are required to achieve proper space closure with low-friction methods; space closure with sliding mechanics is relatively easier and less demanding for the clinician.^{1,2} This ease comes at the cost of increased friction at the bracket-wire interface, and the nature of ligation can affect this friction.^{3–5} Self-ligating brackets were introduced as a means to reduce friction and enable closure of space using physiological forces of considerably low magnitude,^{6–8} but this reduced friction may not always necessarily translate into a shorter treatment time.^{9,10}

Apart from self-ligating brackets, many other attempts have been made to decrease the total treatment time, including surgical and nonsurgical methods. Currently, many investigations have been undertaken to determine the potency of various surgical methods in increasing the rate of space

CONSORT FLOW CHART OF PARTICIPANTS THROUGH EACH STAGE OF THE TRIAL

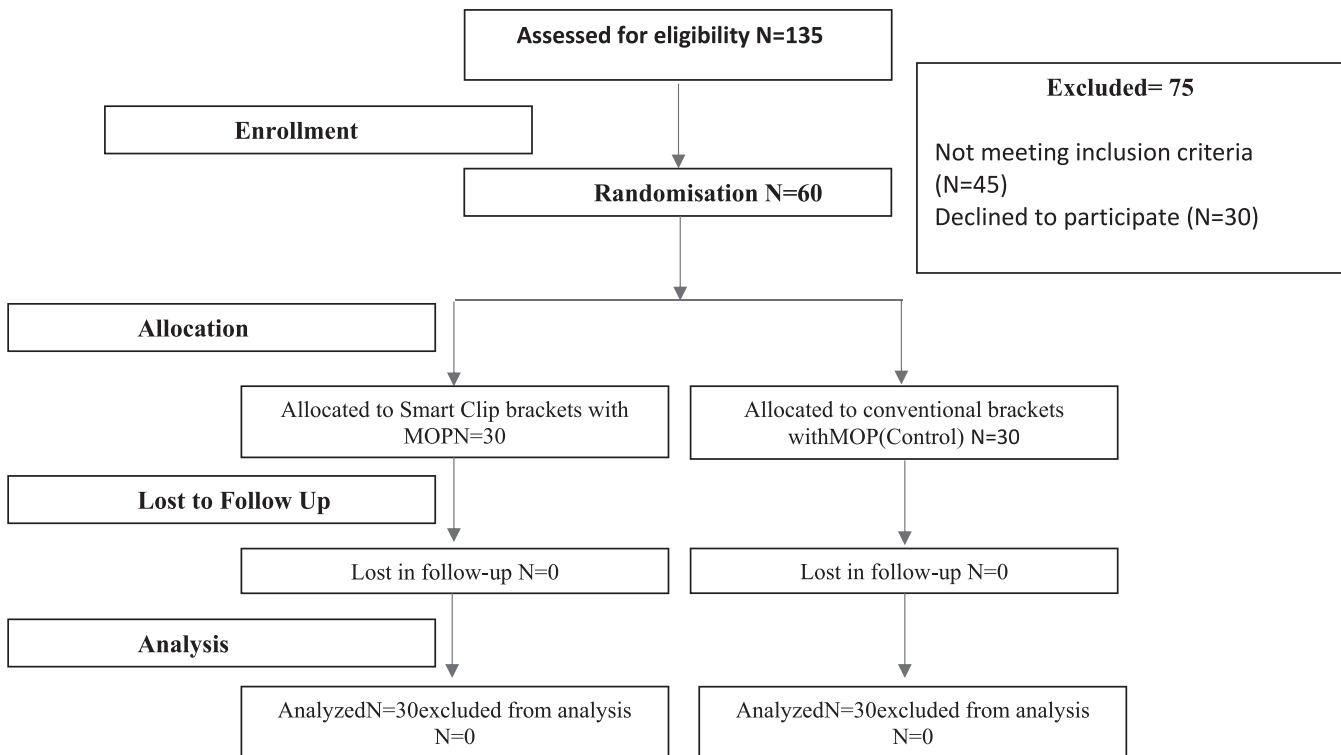


Figure 1. CONSORT flowchart.

closure,¹¹ but some evidence via meta-analysis and randomized controlled trials has indicated that surgical methods may be effective in accelerating the rate of space closure.^{12,13} Micro-osteoperforations (MOPs) of the alveolar bone have been employed to induce microtrauma and initiate a regional acceleratory phenomenon adjacent to the extraction space. Compared with other methods, they can be used easily in a clinical setting by the orthodontist alone. In a recently published randomized controlled trial, it was concluded that MOPs were effective in accelerating the rate of space closure when used with conventional appliances without any added discomfort to the patient.¹⁴ To investigate further, it was hypothesized that a combination of MOPs and low-friction appliances such as passive self-ligating brackets might have a synergistic effect when employed together.

The present trial was conducted to evaluate and compare the rate of space closure in patients undergoing extraction orthodontic therapy between MOPs with passive self-ligating brackets and MOPs with conventional brackets. The null hypothesis was that there would be no difference in the rate of space closure between passive self-ligating appliances and conventional ligating appliances in patients with MOPs.

MATERIALS AND METHODS

Trial Design

The study had an equal allocation ratio with two parallel arms. Patients participating in the trial had given prior consent, and clearance was obtained from the ethical clearance committee of the Institute of Dental Studies and Technologies (IDST/ERB/2014-17/15). The trial was registered at the National Trial Registry (CTRI/2018/03/012331) and was conducted in accordance with the Declaration of Helsinki guidelines¹⁵ and CONSORT guidelines (Figure 1).¹⁶

Participants, Eligibility Criteria, and Settings

The outpatient department of the Institute of Dental Studies and Technologies served as the primary source of the participants for the trial. The trial was initiated in January 2016 with initial screening and was completed in March 2017. Inclusion criteria for the trial included (1) patients in permanent dentition (13–20 years), (2) Little's Irregularity Index of <5 mm with bidental protrusion, (3) treatment plan involving extraction of the first premolars in both arches, (4) healthy periodontal condition, (5) patients with no underlying

systemic conditions, and (6) Frankfurt mandibular angle between 20° and 25°. Exclusion criteria included (1) patients requiring orthognathic surgery, (2) existing medical conditions, (3) patients with active periodontal disease, (4) patients with congenital disorders, (5) patients who underwent prior orthodontic therapy, and (6) patients with underlying skeletal Class II and Class III malocclusion.

Interventions

Patients were randomly assigned to either the experimental or control groups. The experimental group consisted of patients treated with 3M Smart Clip brackets supplemented with MOP. These brackets were considered passive self-ligating appliances despite the use of nickel titanium springs as the archwire was passively held in the bracket slot.¹¹ Finite element analysis revealed that there was no clip stress after the insertion of 0.019 × 0.025-inch stainless steel wire, making the Smart Clip bracket effectively a passive self-ligating bracket.¹⁷ The control consisted of patients treated with 3M Gemini brackets supplemented with MOP. All brackets had the MBT prescription. The first premolars were extracted at the start of the treatment, prior to the commencement of leveling and alignment. Leveling and alignment were accomplished until the 0.019 × 0.025-inch stainless steel wires fit passively.¹⁸ Retraction was initiated after a period of 3 weeks from the completion of leveling and alignment, immediately after MOP, in both groups. En masse retraction was carried out using active tie backs, and the force was standardized at 150 g using a Dontrix gauge. Provisions were made to ensure that every participant received MOPs after exactly 28 days. Second molar banding in both arches and cross-arch (transpalatal arch) stabilization in the maxillary arch served as the anchorage. As the sample included only Class I bidental protrusion cases (none of the participants developed into a Class II or a Class III during the course of space closure), Class I force was used for space closure, and intermaxillary elastics were not employed during the period of space closure. Patients were advised to inform the primary investigator immediately if bracket failure occurred, and the bracket was rebonded after thorough sandblasting to remove any residual composite in the bracket mesh. No bracket failures were reported by any participant during the space closure period. The orthodontic treatment and MOPs were performed by a single orthodontist, and extractions for all participants were done by a single surgeon. All participants were informed about the use of non-steroidal anti-inflammatory drugs and their interference with space closure. Participants were further instructed to inform the primary investigator of

any medication that was taken, if a need arose during the course of space closure. Patient recruitment and treatment were performed by the primary investigator, whereas the data analysis was done by a secondary investigator who was blinded to the patient allocation.

Procedure for MOP

A PROPEL device (Propel Orthodontics, Ossining, NY) was used to perform MOPs. A pointed stainless steel tip (driven manually) was used for cortical bone perforation. The dimension of the tips used was 1.6 mm × 7 mm. Protective sleeves could be used to preset the depths of MOPs at 1 mm, 3 mm, 5 mm, and 7 mm. Chlorhexidine gluconate solution was applied, and topical local anesthetic (2% lidocaine) was sprayed prior to performing MOP. Three vertically oriented perforations were made distal to the canine, which were 1.5 mm in width and 2 to 3-mm deep within the alveolar bone. No mucoperiosteal flaps were raised, and the perforations were made directly through the gingiva. The perforation was made in the edentulous area distal to the canine. Careful approximation of the canine root was made clinically by manual palpation to avoid any accidental perforation of the canine root.

Primary and Secondary Outcomes

The rate of space closure in millimeters per month was the primary outcome, and MOPs were performed throughout the period space closure, every 28 days. Pre- and postretraction models were digitized using a scanner (COMET5, 100-200-400, Steinbichler Optotechnik, Germany), and software was used to make measurements to the nearest 0.001 mm (resolution = $v \pm .000001$ mm). A mid-palatine line was used as the reference for measurements. Perpendicular lines were drawn from the distal surface of the canine to the mesial surface of the second premolar on the reference line. Repeatability and retest reliability were assessed by remeasuring 20 randomly selected patients (10 from each group) by the same assessor after 2 weeks (intraclass coefficient = .88), and the standard error of the mean was found to be statistically not significant. Space closure was confirmed by evaluation of a tight contact between the canine and the second premolar by passing a piece of dental floss.

Randomization

Block randomization was done to achieve an equal number of participants in both groups. Patient case record numbers were used as input in the allocation sequence. The concealed sequences in sealed envelopes were then chosen by the patient. The primary investigator was not involved in randomization.

Table 1. Descriptive Statistics

Descriptive	Group 1 (Experimental)	Group 2 (Control)
Age, y, mean \pm SD	19.5 \pm 1.66	19.9 \pm 1.13
Sex, male/female	16/14	14/16
Mean incisor irregularity (maxilla), mm	2.39 \pm 0.51	2.45 \pm 0.48
Mean incisor irregularity (mandible), mm	2.11 \pm 0.75	2.20 \pm 0.61
Mean preretracted extraction space (maxilla), mm	5.11 \pm 0.74	5.09 \pm 0.85
Mean preretracted extraction space (mandible), mm	5.14 \pm 0.64	5.16 \pm 0.61

Sample Size Calculation

Calculations for the sample size were done using the nMaster 2.0 software. A power analysis was done based on the space closure data of a previous published study,¹⁴ which indicated that 21 patients per group were needed (80% power, α error = .05, Cohen's effect size .8). To further increase the power, it was decided to enroll a sample of 30 per group.

Blinding

The models were coded to blind the investigator performing data analysis to the identity of the two groups. Blinding of the participants and the primary investigator was not possible because of the nature of the trial.

Statistical Analysis

SPSS software (version 20.0; SPSS Inc, Chicago, Ill) was used. Baseline pretreatment parameters (Table 1) were compared using independent *t*-tests to ensure uniformity of the data. Normality of the data was checked using Shapiro-Wilk tests (Table 2) and was found to be normally distributed. The average rate of space closure was calculated as:

Available extraction space after leveling and alignment \times 28 days/days taken for the closure of extraction space.

Table 2. Shapiro-Wilk Normality Tests

Parameter	Statistic	Degree of Freedom	Significance
Monthly rate of space closure (right side maxilla)	.984	60	.248
Monthly rate of space closure (left side maxilla)	.954	60	.277
Monthly rate of space closure (right side mandible)	.955	60	.236
Monthly rate of space closure (left side mandible)	.974	60	.301

Mean and standard deviation were used to describe the data, and independent *t*-test was used to check for statistically significant differences ($P < .05$) in the rate of space closure between the two groups (Table 3).

RESULTS

Of the 135 subjects who were evaluated for the trial, 45 did not meet the inclusion criteria, and 30 were not willing to participate. A total of 60 participants (30 men and 30 women) were enrolled, and none of the participants were lost during the trial. Evaluation of pretreatment baseline values showed no differences between the two groups. Independent *t*-test was used to analyze differences between the groups. No statistically significant difference between the two groups was observed (Table 3). The mean rate of space closure per month in the experimental group was 0.81 \pm 0.07 mm for the maxilla (right), 0.81 \pm 0.12 mm for the maxilla (left), 0.78 \pm 0.08 mm for the mandible (right), and 0.77 \pm 0.15 mm for the mandible (left). In the control group, it was 0.79 \pm 0.05 mm for the maxilla (right), 0.80 \pm 0.12 mm for the maxilla (left), 0.78 \pm 0.11 mm for the mandible (right), and 0.78 \pm 0.07 mm for the mandible (left; Table 3). The total time for space closure was 190 \pm 9 days for the maxilla and 200 \pm 6 days for the mandible.

Harms

Accidental root perforation was the only known potential harm evaluated for the study. No such incidents were reported.

DISCUSSION

The results of the study indicated that there was no additional enhancement in the rate of space closure when MOP was combined with a low-friction environment provided by a self-ligating appliance. Friction and subsequent force loss were previously shown to be influenced by the bracket type.¹⁹ Low levels of static and dynamic friction were observed in association with passive self-ligating brackets^{20,21}; however, this was observed only in vitro. Some authors found an increased rate of space closure,²² but most of the literature pointed toward the ineffectiveness of self-ligating brackets in increasing the rate of space closure.^{23–25} MOPs were shown to be effective in increasing the rate of space closure, but their efficacy in a low-friction environment was not previously evaluated.

Various methods have been described in the literature for speeding up space closure.^{11,26} However, only recently have attempts been made to combine the two methods and check for any synergistic effect the

Table 3. Comparisons of Rate of Space Closure (mm/mo) Between the Groups

Variable, mm	Group 1 (Experimental), Mean \pm SD	Group 2 (Control), Mean \pm SD	Mean Difference	Standard Error of Difference	95% Confidence Interval		P Value
					Lower	Upper	
Monthly rate of space closure (right-side maxilla)	0.81 \pm 0.07	0.79 \pm 0.05	0.014	0.31	-0.05	0.08	.651
Monthly rate of space closure (left-side maxilla)	0.81 \pm 0.12	0.80 \pm 0.12	0.007	0.054	-0.10	0.12	.89
Monthly rate of space closure (right-side mandible)	0.78 \pm 0.08	0.78 \pm 0.11	0.008	0.044	-0.10	0.85	.859
Monthly rate of space closure (left-side mandible)	0.77 \pm 0.15	0.78 \pm 0.07	0.028	0.054	-0.14	0.08	.615

two techniques might have when employed together. A recent study was done to assess the combination of low-level laser therapy and MOPs to enhance the rate of space closure. The combination was then compared with the individual methods separately.²⁷ The authors concluded that the combination was more effective than the application of each technique separately. A similar synergistic effect may be observed if MOPs are combined with any other technique. Because the low friction provided by the self-ligating appliances had not been effective clinically in previous studies, combining them with MOPs might have provided a similar synergistic effect.²⁷ Heavy orthodontic forces are usually required to overcome friction before space closure can be initiated, which may result in hyalinization and slowing of tooth movement.²⁸ Lower friction and the longer reactivation schedule associated with passive self-ligating appliances and MOPs might have provided an environment in which faster space closure was possible.

It was essential to standardize the age of the participants in the two groups, as it has been shown that the age of the patient does have a bearing on the rate of space closure.²⁹ There was no statistically significant difference in mean age between the groups. Also, participants included in the trial had an average Frankfort-mandibular plane angle (FMA) (20°–25°), as a vertical growth pattern might be associated with the bite force, which in turn might have affected the rate of space closure.³⁰

The rate of tooth movement in the present trial was slower than the rate associated with MOPs in the literature. This variation may have been due to the use of different archwires and inconsistent forces in moving canines, measurement methods, and operative methods employed in the different trials. Or there may have been operator bias, as blinding was not possible in this trial.

Archwire binding has been shown to play an important role once the contact angle between the archwire and the slot increases beyond 3.7°.³¹ However, in the present trial, retraction was done on a 0.019 \times 0.022-inch stainless steel archwire in a 0.022 \times 0.028-inch slot. The critical contact angle for this archwire-

bracket slot combination has been shown to be less than 3.7° for any given bracket width.³²

To compensate for the force decay of elastomeric ligatures during space closure, ligatures used in this trial were from a single manufacturer. As the maximum force decay is known to occur within 24 hours and then declines before reducing further after 4 weeks, the elastomeric module active tie backs were replaced every 28 days.³³

Limitations of the Study

To address a nonlinear event such as space closure, a summary table could have been used. In this study, millimeters/month was used to quantify the rate of space closure, following established protocols.³⁴

Generalizability

The results can be applied in a typical clinical scenario as the trial was conducted in an accredited and recognized dental college in an outpatient setting, which could mimic a typical orthodontic case load. Orthodontic therapy was provided by postgraduate resident doctors under faculty supervision.

CONCLUSION

- MOP in conjunction with passive self-ligation does not offer any additional synergistic benefit in increasing the rate of orthodontic space closure.

DISCLOSURES

The authors declared no conflict of interest. There was no external source of funding for this trial.

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