A comparison of the rate of en-masse space closure using conventional and passive self-ligating brackets with closed-coil springs

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Abstract. Malocclusion prevalence is high, and an orthodontist needs to be effective and efficient in treating malocclusion. Self-ligating brackets are claimed to be more effective and efficient, and to have less friction in ortodontic movement than do conventional brackets. The objective of this study is to compare the rate of mandibular en-masse space closure retraction and loss of anchorage between passive self-ligating brackets and conventional brackets using closed-coil springs. The study design was a prospective randomized controlled clinical trial with split-mouth technique. Twenty two mandibular quadrants in patients that were ready for en-masse space closure retraction were placed with conventional brackets MBT Agile 3M slot.022" in a whole quadrant, while the contra lateral was placed with passive self-ligating brackets Damon Q standar torque Ormco. The en-masse space closure retraction rate and loss of anchorage were measured in study models at 4 and 8 weeks. The results indicated there was significant difference between passive self-ligating brackets and conventional brackets regarding the en-masse space closure retraction rate and loss of anchorage rate. Self-ligating brackets were faster in en-masse space closure with a mean rate 0.58mm in 4 weeks and 0.74mm in 8 weeks and they were more resistant to loss of anchorage. The split-mouth technique was effective for comparison of the rate of mandibular en-masse retraction and loss of anchorage between self-ligating brackets and conventional brackets using closed-coil springs, where individual variability was minimized.

1. Introduction

The prevalence of malocclusion in Indonesia is quite high [1]. Malocclusion or imperfect teeth occlusion will affect not only the physical aspect but also the psychological, aesthetic and social aspects of an individual's life. Orthodontic treatment is crucial to convert malocclusion into optimal occlusion to improve the quality of life. The necessity of malocclusion treatment is becoming greater, while the limited number of orthodontists requires them to work effectively and efficiently. A conventional system of fixed orthodontic treatment has some limitations such as difficulty in maintaining the full attachment of wires to brackets, fairly high friction, elastomeric force decay, and a relatively long amount of time needed for ligation [2]. These limitations have led clinicians and researchers to keep trying to develop a bracket system that diminishes the limitations of conventional systems. Self-ligating brackets accommodate the limitations of conventional bracket systems where the brackets are directly ligated to the component of the bracket itself.

Self-ligating brackets achieve optimal and secure wire attachment on the bracket slot, create less friction, and enable easier and faster tooth movement with less force. This increases a patient's

IOP Conf. Series: Journal of Physics: Conf. Series **884** (2017) 012097 doi:10.1088/1742-6596/884/1/012097

comfort and the ease of attaching and releasing the wire on the bracket, and shortens control time [3]; thus they are more effective and time-efficient. In-vitro research conducted by Shivapuja [4], Thorstenson [5], Hain [6], Badawi [7], Krihnan [8], and Stefanos [9] stated that self-ligating brackets have less friction, easier tooth movement, and less time is needed for attaching and releasing the bracket in comparison to conventional brackets [6]. Clinical research conducted by Miles [10], Pandis [11], Scott [12], Fleming [13,14], DiBiase [15], and Johansson [16] could not prove with statistical significance that efficiency, effectiveness, and duration of orthodontic treatment with self-ligating brackets is the same as with conventional brackets. However, this could be the result of a lack of some data such as difference in the skill of orthodontic treatment, variations of anatomical structure in each individual, diversity of teeth crowding irregularities in each patient, and an inadequate number of samples.

Clinical research conducted by Miles [17], Burrow [18], and Mezomo [19] compare the speed for diastema closure between self-ligating brackets and split-mouth conventionally, but only on the canine or posterior region with different brackets; meanwhile the anterior region was still treated using conventional brackets (undifferentiated) [18]. This may affect the sliding mechanism which is supposed to happen on self-ligating brackets, thus producing relatively the same movement between the two systems [18]. Research has not yet been done which clinically compares the speed of diastema closure between conventional brackets and self-ligating brackets with a comprehensive split-mouth technique, and comparing the loss of anchorage has not been done yet. In general, this research aims to discover the difference in the speed of diastema closure and the loss of anchorage between regions with MBT pre-adjusted conventional brackets and Damon Q self-ligating brackets with closed-coil spring activation.

2. Materials and Methods

This research is a randomized controlled clinical trial prospective study using split-mouth technique. Samples were obtained from the Dental Hospital Faculty of Dentistry of Universitas Indonesia. Ethical approval was obtained from the Ethics committee of the Faculty. The samples were taken just before en-masse retraction of 6 anterior teeth (T0), at the 4 week control (T1), and at the 8 week control (T2) from February to November 2013. The subjects of this research were patients who were willing to be treated with fixed orthodontics, with the indication to extract all four first premolars with split-mouth design randomly; who had gone through the aligning and levelling treatment phase; and who were ready to continue to space-closure phase using SS.019x.025 wire passively for 2 weeks on .022" bracket slot. Measurement was conducted only for the mandible. A 0.022" slot of pre-adjusted MBT bracket was installed on one region and a 0.022" slot of self-ligating passive Damon Q was installed on the contralateral.

The inclusion criteria were: male or female patients between 15-37 years of age who were willing to be subjects of the study; had undergone full growth; had not reached menopause (for females); had good periodontal tissue; were not consuming medicines or NSAIDs that would affect the inflammation process of periodontal tissue; and did not have a history of medical or drug therapy that could influence the development of the jaw structure or movement of the teeth. Patients were in need of fixed orthodontic treatment with the extraction of all four first premolars, had undergone the aligning and levelling phase of treatment and were entering the space-closure phase using SS.019x.025 wire passively for 2 weeks, with no other tooth loss beside the third molar.

To determine the split-mouth sample group, eleven subjects were randomly divided into 2 groups with Damon Q passive self-ligating brackets on the right region and MBT pre-adjusted conventional brackets on the left region for Group A, and vice versa for Group B. All subjects were patients who fit into the inclusion criteria, who had undergone levelling and aligning, and who would go through the space closure phase and had reached SS.019x.025 working wire. The passive phase was conducted; SS.019x.025 working wire was passive for 2 weeks inside the oral cavity. Bracket debonding on the split mouth region was done according to Group A or B randomization. The installation of the bracket on split mouth region was done according to Group A or B design with the guidance of SS.019x 0.025

working wire from the bracket of the first incisive to the second incisive until the buccal tube of the first molar. The installation of SS.019x 0.025 retraction wire, and the installation of posted hook on SS.019x 0.025 wire was done on the distal portion of the second incisive that had been marked before. Teeth impressions were taken as a study model of the beginning of space closure (T0) before the next activation. Before the teeth impressions, all brackets were covered using orthodontic wax as a double blind for the operator in measurement. Model identification could only be done from the model number; thus the researcher doing measurements would have no idea whether conventional brackets or self-ligating brackets were installed in each region.

Figure 1. Top, double blind with orthodontic wax before impression. Below, space closure with split mouth technique, conventional bracket for lower right region, self-ligating bracket for lower left region

The activation of en-masse retraction using close-coil spring with 150 gr force with tension gauge on each mandible region was done from crimpable hook wire to the buccal tube of the first molar of the mandible (Figure 1). The phase of collecting the sample from number 1 to number 2 was repeated at control /4 weeks activation (T1) and 8 weeks (T2) space closure post tooth extraction Thus a model for each sample was obtained at T0, T1, and T2. Closed coil spring was not replaced on each control/activation, but the force stability of 150 gr was maintained instead. The elastomeric (power 0) was replaced with a new one every control/activation. The measurements of speed of space closure and anchorage loss were conducted on the model after all of the samples were obtained. The measurement was conducted 3 times, the mean value was taken, and the measurement was repeated after 7 days to obtain reliability. The en-masse retraction of anterior teeth was analysed post extraction from the distal point of the canine to the mesial contact of the second premolar, using a Massel electronic digital calliper. The measurement on the study model before retraction T0 was deducted with the study model after 4 weeks retraction T1 (RT0-T1) and T1 was deducted by T2 (RT1-T2).

The activation of en-masse retraction using close-coil spring with 150 gr force with tension gauge on each mandible region was done from crimpable hook wire to the buccal tube of the first molar of the mandible (Figure 1). The phase of collecting the sample from number 1 to number 2 was repeated at control /4 weeks activation (T1) and 8 weeks (T2) space closure post tooth extraction Thus a model for each sample was obtained at T0, T1, and T2. Closed coil spring was not replaced on each control/activation, but the force stability of 150 gr was maintained instead. The elastomeric (power 0) was replaced with a new one every control/activation. The measurements of speed of space closure and anchorage loss were conducted on the model after all of the samples were obtained. The measurement was conducted 3 times, the mean value was taken, and the measurement was repeated after 7 days to obtain reliability. The en-masse retraction of anterior teeth was analysed post extraction from the distal point of the canine to the mesial contact of the second premolar, using a Massel electronic digital calliper. The measurement on the study model before retraction T0 was deducted with the study model after 4 weeks retraction T1 (RT0-T1) and T1 was deducted by T2 (RT1-T2).

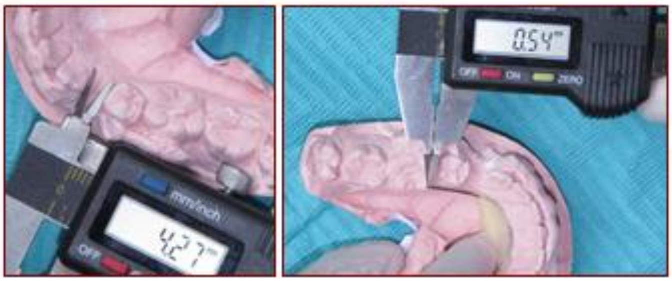

Figure 2. Left, measurement of space closure on model. Right, measurement of anchorage loss on model with the guidance of wire attached to the acrylic

Anchorage loss was measured on the mandible study model of T1 (AT0-T1) and T2 (AT0-T2) compared to T0 using an acrylic guide on the lingual side of the mandible arch and the spina mentalis of the mandible anatomical structure. The guide, made from SS wire with a diameter of 0.7 mm, was attached to self-curing acrylic resin on the lingual of the mandible and the spina mentalis from the acrylic to the mesiolingual cusp of the mandible first molar on the T0 study model before retraction. The measurement was conducted by installing acrylic auxiliary tools on the spina mentalis and corpus mandible anatomical structure with wire from the T0 study model to be attached to the T1 and T2 study models (Figure 2). The acrylic auxiliary tool on the lingual of mandible anatomy was used as a guide in repositioning the same skeletal condition on the mandible, allowing measurement of the movement of anchorage loss on the study model before and after the retraction. Measurement was conducted using a Massel digital calliper from the end of the wire embedded in the acrylic on the T0 study model to the cusp of the mesiolingual that had been marked on the T1 (AT0-T1) and T2 (AT1-T2) study models (Figure 2). Measurement was conducted 3 times and the mean value was obtained, then measurement was repeated after 7 days with the same methods to ensure reliability.

3. Results and Discussion

3.1 Results

Eleven respondents were treated with split-mouth method where all subjects were given two treatments simultaneously. Respondents were made up of 3 males aged 19 to 24 years old and 8 females aged 15 to 37 years old with the mean value of age being 25.9 years old, and a standard deviation of ±7.2 years. An intra-observer examination was conducted with the Bland-Altman plot to measure the suitability and consistency of the researcher on repeating the measurement with the same methods and to figure out any systematic error. The Bland-Altman plot graphic is shown in Figure 3, measuring the speed of space closure on conventional and passive self-ligating brackets from T0 before retraction, to T1 after 4 weeks of retraction and T2 after 8 weeks of retraction.

The Bland-Altman plot in Figure 3 shows the suitability from data 1 and data 2 measurements. Bias or the mean value of data 1 and data 2 measurement differences is zero value. There is 95% limit of agreement from -0.031 to 0.031 mm. Most of the plot is distributed between the bias line and inside the limit of agreement line. There is a high level of agreement. There are two points outside the limit of agreement that can be ignored because more than 95% of the points are distributed inside the limit of agreement. The Bland-Altman plot for the methods of measuring anchorage loss on conventional and passive self-ligating brackets for T1 and T2 was compared between data 1 and data 2 measurements with the same measurement methods and the same researchers (Figure 4). It can be concluded from the graphic that there is suitability between the measurement of anchorage loss on data 1 and data 2. It is concluded from the bias of data 1 and data 2, which is zero with tight limits of agreement from – 0.029 to 0.029 mm, that most of the plots are distributed between the bias line and inside the limit of agreement. There is a high level of agreement.

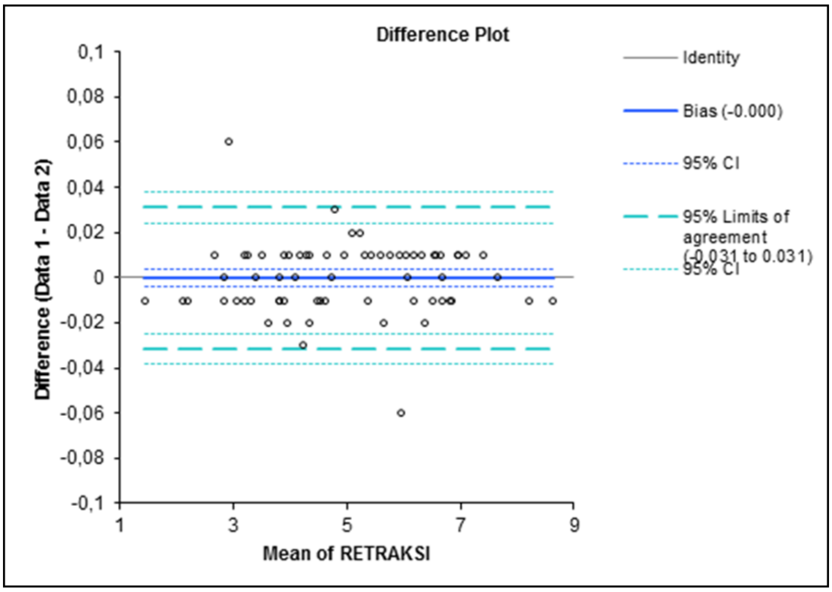

Figure 3. Bland-Altman plot measurement of the speed of space closure of conventional and passive self-ligating bracket on T0, T1, and T2 on the measurement of data 1 and data 2

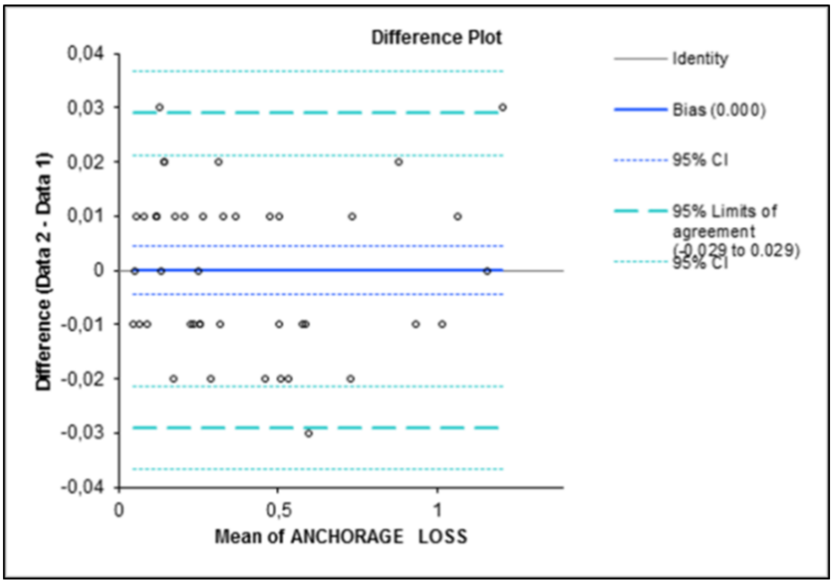

Figure 4. Bland-Altman plot on the measurement of anchorage loss from conventional and passive self-ligating brackets on data 1 and data 2 measurement

Saphiro-Wilk normality test of the space closure speed and the anchorage loss distribution was done on the conventional brackets group and the passive self-ligating group on T0, T1, and T2. Table 1 shows normal data distribution from every group because the $p > 0.05$, except on the self-ligating space closure group, T0-T1 $p = 0.001$ and the conventional space closure group, T1-T2 $p = 0.001$. The distribution on both groups is abnormal because $p < 0.05$. Data from the self-ligating space closure group T0-T1 and the convention space closure group T1-T2 is abnormal and cannot be transformed. The data distribution of the self-ligating space closure group at T0-T1 and the conventional group at

IOP Conf. Series: Journal of Physics: Conf. Series **884** (2017) 012097 doi:10.1088/1742-6596/884/1/012097

T1-T2 led to use of the Wilcoxon Test to analyse the retraction hypothesis group. Meanwhile, for the anchorage loss group where all data distribution is normal, a T-Paired test analysis was conducted.

Table 1. Normality test of conventional and self-ligating data distribution on space closure speed and anchorage loss on T0-T1 and T1-T2 period.

Group	Measurement	Period	p-value
Self-ligating	Space closure	T0-T1	0.001
		T1-T2	0.189
	Anchorage loss	T0-T1	0.179
		T1-T2	0.202
Conventional	Space Closure	T0-T1	0.751
		T1-T2	0.001
	Anchorage loss	T0-T1	0.088
		T1-T2	0.238

$p < 0.05$ = abnormal data distribution

The measurement of the space closure speed between the conventional brackets region and the passive self-ligating group in the T0-T1 and T1-T2 period was analysed by Wilcoxon test as can be seen in Table 2.

Table 2. Mean value, standard deviation, and wilcoxon test result of space closure speed between passive self-ligating bracket and conventional in T0-T1 and T1-T2 period

Period	Mean Value ± SD (mm/4 weeks)		p-value
	Passive Self Ligating	Conventional	
T0-T1	0.58 ± 0.25	0.39 ± 0.15	0.03
T1-T2	0.74 ± 0.28	0.59 ± 0.32	0.037

$p < 0.05$ = statistically different

The hypothesis stating that there is a difference in space closure speed post teeth extraction with en-masse retraction between MBT pre-adjusted conventional brackets region group and Damon Q passive self-ligating brackets region group at 4 weeks activation with closed-coil spring (RT0-T1) is accepted because $p < 0.05$ (Table 3). The hypothesis stating that there is a difference in space closure speed post teeth extraction with en-masse retraction between MBT pre-adjusted conventional brackets region group and Damon Q passive self-ligating brackets region group at 8 weeks activation with closed-coil spring (RT1-T2) is accepted because $p < 0.05$ (Table 2).

Table 3. Mean value, standard deviation, and wilcoxon test result of space closure speed between T0-T1 and T1-T2 period on passive self-ligating bracket and conventional bracket

Group	Mean Value ± SD (mm/4 weeks)		p-value
	T0-T1	T1-T2	
Passive Self Ligating	0.58 ± 0.25	0.74 ± 0.28	0.03
Conventional	0.39 ± 0.15	0.59 ± 0.32	0.03

$p < 0{,}05$ = statistically different

The hypothesis stating that there is a difference in space closure speed post teeth extraction with en-masse retraction between T0-T1 and T1-T2 on group using MBT pre-adjusted conventional bracket with closed-coil spring activation is accepted because $p< 0.05$ (Table 3).The hypothesis stating that there is a difference in space closure speed post teeth extraction with en-masse retraction between T0-T1 and T1-T2 on group using Damon Q passive self-ligating bracket with closed-coil spring activation is accepted because $p< 0.05$ (Table 3). The hypothesis regarding anchorage loss was tested using T-Paired examination due to normal data distribution for the anchorage loss group.

Table 4. Mean value, standard deviation, and value of t-paired examination of anchorage loss between passive self-ligating bracket and conventional bracket on T0-T1 and T1-T2 period

Period	Mean Value ± SD (mm/4 weeks)		p-value
	Passive Self Ligating	Conventional	
T0-T1	0.14 ± 0.09	0.3 ± 0.19	0.001
T1-T2	0.23 ± 0.16	0.35 ± 0.17	0.000

p <0,05 = statistically different

The hypothesis stating that there is a difference of anchorage loss on en-masse retraction between MBT pre-adjusted conventional brackets region group and Damon Q passive self-ligating brackets region group at 4 weeks activation with closed-coil spring (AT0-T1) is accepted because $p < 0.05$ (Table 4). The hypothesis stating that there is a difference of anchorage loss on en-masse retraction between the MBT pre-adjusted conventional brackets region group and the Damon Q passive self-ligating brackets region group at 8 weeks activation with closed-coil spring (AT1-T2) is accepted because $p < 0.05$ (Table 4).

Table 5. Mean value, standard deviation, and value of t-paired examination of anchorage loss between T0-T1 and T1-T2 period on passive self-ligating bracket and conventional bracket.

Group	Mean Value ± SD (mm/4 weeks)		p-value
	T0-T1	T1-T2	
Passive Self-Ligating	0.14 ± 0.09	0.23 ± 0.16	0.000
Conventional	0.3 ± 0.190	0.35 ± 0.17	0.000

p <0.05 = statistically different

The hypothesis stating that there is a difference in anchorage on en-masse retraction between T0-T1 and T1-T2 for the group using MBT pre-adjusted conventional brackets with closed-coil spring activation is accepted because $p < 0.05$ (Table 5). The hypothesis stating that there is a difference in anchorage on en-masse retraction between T0-T1 and T1-T2 for the group using Damon Q passive self-ligating brackets with closed-coil spring activation is accepted because $p < 0.05$ (Table 5).

3.2 Discussion
Orthodontic treatment with first premolar extraction is a case frequently encountered by orthodontists. Skill and time efficiency in treating a case are demanded from an orthodontist. Self-ligating brackets

claim to offer better efficiency than conventional brackets due to better resistance to friction. There are a number of studies comparing the efficiency of passive self-ligating brackets with conventional brackets from the initial alignment phase to leveling and aligning; however, there are very few studies exploring the next phase, which is the space closure phase. Wong (2013) [20] compared the retraction speed between Damon 3MX passive self-ligating brackets and conventional brackets which are ligated by elastomeric and by super slick in the space closure phase simultaneously, with as many as 13 samples in each group. En-masse retraction was conducted using NiTi coil spring with coil spring stretching activation twice each month. Wong's research did not show any statistical differences between groups; this may be due to the large variety between samples. This research used a split-mouth method in which one individual received two different treatments. The split-mouth method is considered to be effective for observing the difference in space closure speed and anchorage loss on both bracket systems. This is done to minimize the probability of large variation from each sample, allowing every treated region that will be compared with another region on the contra lateral side to react equally, thus decreasing the individual variation that could interfere with the analysis. The split-mouth method is one in which the treatment side being compared will be considered to react equally or almost equally with the other treatment side in the same individual. This method reduces the amount of samples needed. Thus, according to Pandis (2012), the amount of the samples is far less than in research without the split-mouth method or in parallel methods because it reduces variability, in the calculation of sample amounts on split-mouth design [21].

Observation and analysis using split-mouth design is a paired analysis. With split-mouth design, the treatment and the control sides are in one individual, in paired observation, and are considered to react non-substantially and minimize variability, allowing far better efficiency [21]. Split-mouth design is very compatible and effective in measuring different treatments in one individual. This method is not compatible, and will affect and increase the co-founding factors, if it is used to find plaque reduction effectiveness with two different anti-bacterial mouthwashes. The risk in this design is that one treatment will contaminate the other side receiving different treatment, interfering with further measurement [21]. Estimation of the appropriate amount of samples is the most important thing in clinical trial methodology; dosage is related to precision and the strength of results obtained from the research [22,23]. Research with the scientifically correct amount of samples is ethically justified and has more credibility compared to research with an insufficient amount of samples. The planning of a clinical trial with insufficient amount of sample can be considered a waste of time and resources, and unethical because there is a probability that the patient in the research is being given a treatment that could produce a less optimal treatment and it will affect clinical practice [22].

The amount of samples in this research is calculated based on standard deviation from Dixon (2002) comparing the speed of retraction between active ligature, power chain, and NiTi coil spring, with the amount of samples of each consecutive group being 12, 10 and 11 samples [24]. The minimum mean difference that is considered to be significant in this research is 0.85 mm. Therefore, the amount of samples obtained is 11 samples, whereas Wong (2013), comparing the retraction speed between conventional brackets and self-ligating brackets with parallel technique without the split-mouth method, conducted a research with 13 samples in each group. Based on both journals mentioned above, studies assume that 11 samples are enough with the split-mouth method. In general, the space closure speed on the first four weeks, RT0-T1 is less than the space closure speed on week 8, RT1-T2 for both the conventional brackets system and the passive self-ligating brackets system. This is also the case for anchorage loss measurement at week 4; AT0-T1 is less than week 8 for both the conventional brackets system and the passive self-ligating brackets system. This could be due to the fact that, for the initial retraction in week 4, the inflammation process of alveolar bone (with apposition and resorption of the alveolar bone) has just began, while the second retraction in week 8 occurs when inflammation is already in progress. Thus, reposition and apposition of alveolar bone is faster, allowing faster tooth movement. Generally, the space closure speed of passive self-ligating bracket groups is statistically different from conventional brackets on both the first retraction at week 4 (T0-T1) and on the second retraction at week 8 (T1-T2). This clinically proves that teeth retraction using this method is easier using passive self-ligating brackets in comparison with conventional brackets. This is probably due to less friction on self-ligating brackets compared to the friction of conventional brackets [17-22,25,26]. The same amount of controlled force produced larger amounts of retraction on self-ligating brackets compared to conventional brackets.

Likewise, on the measurement of anchorage loss, the passive self-ligating brackets have statistically smaller differences than conventional bracket systems at both T0-T1 and T1-T2. This could be due to the tissue resilience for self-ligating brackets being better in comparison with conventional brackets, allowing less anchorage loss. The space closure speed of passive self-ligating brackets is significantly larger for the first retraction T0-T1 compared to the second retraction T1-T2. This is also the case for conventional brackets; the first retraction T0-T1 is significantly different compared to the second retraction T1-T2. This phenomenon also happened with the anchorage loss measurement, where all hypotheses are accepted and significantly different. NiTi closed-coil spring was chosen due to high resistance to Tripolt permanent deformation [27], giving constant force in comparison to elastomer and allowing faster space closure post extraction. 150 gr extraction force on each side is considered the most effective and efficient to close space according to Samuels [28,29], giving optimal movement that is important for biological response of teeth and periodontal tissues, and avoiding too much force. The most important factor for good biological response from the periodontal tissues is the duration of the force given, rather than the magnitude of the force used. Light continuous force will produce optimum force; the use of large force in the beginning of space closure could enlarge the force decay. NiTi closed-coil springs can accommodate the necessary constant force, producing effective tooth movement [29].

The measurement of space closure speed was performed by putting landmarks on the largest embrasure of the contact on the distal side of the canine and the embrasure contact of the mesial side of the second premolar on the T0 study model; this could be used as a guide for the measurement of the T1 and T2 study models with the same landmark, using a digital calliper with 0.00 mm sensitivity. Likewise, on anchorage loss measurement, a point is given on the mesiolingual cusp tip as a guide, allowing measurement from the same position on the T0, T1, and T2 study models to the end of the wire guide. There were some difficulties in the measurement of anchorage loss since the guiding point was too small, difficult to be seen, and highly sensitive to the digital calliper, thus the necessity for an auxiliary tool to assist visibility from the end of the wire guide to the guiding point. This auxiliary tool could be a loop or something similar. The measurement of anchorage loss on the mandible with an acrylic guide on the mandible anatomical landmark is a bit more difficult to perform on study models made from alginate impressions. Higher precision impression such as double impression is needed for the mandible impression, allowing acrylic guide repositioning on the mandible anatomical landmark. Further research using varieties of measurement methods with higher precision, and better tools and materials, is a necessity. Clinicians need to consider the choices of bracket systems for treatment planning according to the each patient and case.

4. Conclusion

There were significant differences in space closure and anchorage loss between the conventional brackets group and the passive self-ligating brackets group for both the T0-T1 period and the T1-T2 period. There was a significant difference in space closure and anchorage loss between T0-T1 period and T1-T2 period for both the conventional brackets group and the passive self-ligating brackets group. This could be due to less friction and better tissue resilience on self-ligating brackets.

References

[1] Oktaviana D 2008 *Analisis hubungan maloklusi dengan kualitas hidup pada remaja SMU kota Medan tahun 2007* Theses Paper [cited September 15th 2012]. Available from: http://repository.usu.ac.id/bitstream/123456789/669/1/08E00229.pdf
[2] Harradine N 2008 The history and development of self-ligating brackets. *Semin. Orthod.* **14** 5-18.

[3] Stolzenberg J 1935 The Russell attachment and its improved advantages. *Int. J. Orthod. Dent. Child*. **21** 837-40.
[4] Shivapuja P K and Berger J 1994 A comparative study of conventional ligation and self-ligation bracket systems. *Am. J. Orthod. Dentofacial Orthop*. **106** 472-80.
[5] Thorstenson G A and Kusy R P 2001 Resistence to sliding of self-ligating brackets versus conventional stainless steel brackets with second-order angulation in the dry and wet (saliva) states. *Am. J. Orthod. Dentofacial Orthop*. **120** 361-70.
[6] Hain M, Dhopatkar A and Rock P 2006 A comparison of different ligation methods on friction. *Am. J. Orthod. Dentofacial Orthop*. **130** 666-70.
[7] Badawi H M, Toogood R W, Carey J P, Heo G and Major P W 2008 Torque expression of self-ligating brackets. *Am. J. Orthod. Dentofacial Orthop*. **133** 721-8.
[8] Krihnan M, Kalathil S and Abraham K M 2009 Comparative evaluation of frictional forces in active and passive self-ligating brackets with various archwire alloys. *Am. J. Orthod. Dentofacial Orthop.* **136** 675-82.
[9] Stefanos S, Secchi A G, Coby G, Tanna N and Mante F K 2010 Friction between various self-ligating brackets and archwire couples during sliding mechanics. *Am. J. Orthod. Dentofacial Orthop*. **138** 463-7.
[10] Miles P G, Weyant R J and Rustveld 2006 A clinical trial of Damon 2 vs conventional twin brackets during initial alignment. *Angle Orthod*. **76** 480-5.
[11] Pandis N, Polychronopoulou A and Eliades T 2007 Self-ligating vs conventional brackets in the treatment of mandibular crowding: A prospective clinical trial of treatment duration and dental effects. *Am. J. Orthod. Dentofacial Orthop*. **132** 208-15.
[12] Scott P, DiBiase A T, Sherriff M and Cobourne M T 2008 Alignment efficiency of Damon3 self-ligating and conventional orthodontic bracket systems: A randomized clinical trial. *Am. J. Orthod. Dentofacial Orthop*. **134, 470** e1-e8.
[13] Fleming P S, DiBiase A T, Sarri G and Lee R T 2009 Efficiency of mandibular arch alignment with 2 preadjusted edgewise appliances. *Am. J. Orthod. Dentofacial Orthop.* **135** 597-602.
[14] Fleming P S, DiBiase A T, Sarri G and Lee R T 2009 Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances. *Am. J. Orthod. Dentofacial Orthop*. **136** 340-7.
[15] DiBiase A T, Nasr I H, Scott P and Cobourne M T 2011 Duration of treatment and occlusal outcome using Damon3 self-ligating and conventional orthodontic bracket systems in extraction patients: A prospective randomized clinical trial. *Am. J. Orthod. Dentofacial Orthop*. **139** e111-6.
[16] Johansson K and Lunstrom F 2012 Orthodontis treatment efficiency with self-ligating and conventional edgewise twin brackets: A prospective randomized clinical trial. *Angle Orthod*. **82**, 929-34.
[17] Miles P G 2007 Self-ligating vs conventional twin brackets during en-masse space closure with sliding mechanics. *Am. J. Orthod. Dentofacial Orthop*. **132** 223-5.
[18] Burrow J 2010 Canine retraction rate with self-ligating brackets vs conventional edgewise brackets. *Angle Orthod*. **80** 626-33.
[19] Mezomo M, de Lima E S, de Menezes M, Weissheimer A and Allgayer S 2011 Maxillary canine retraction with self-ligating and conventional brackets: A randomized clinical trial. *Angle Orthod*. **81** 292-97.
[20] Wong H, Collins J, Tinsley D, Sandler J and Benson P 2013 Does the bracket ligature combination affect the amount of orthodontic space closure over three months? A randomized controlled trial. *J. Orthod*. **40** 155-162.
[21] Pandis N 2012 Sample calculation for split-mouth designs. *Am. J. Orthod. Dentofacial Orthop*. **141** 818-9.

[22] Pandis N, Polychronopoulou A and Elliades T 2011 Sampel size estimation: An overview with applications to orthodontic clnical trial designs. *Am. J. Orthod. Dentofacial Orthop*. **140** e141-6.
[23] Samuels R H A, Rudge S J and Mair L H 1993 A comparison of the rate space closure using a nickel-titanium spring and an module: A clinical study. *Am. J. Orthod. Dentofacial Orthop*. **103** 464-7.
[24] Dixon V, Read M J F, O'Brien K D, Worthington H V and Mandall N A 2002 A randomized clinical trial to compare three methods of orthodontic space closure. *J. Orthod*. **29** 31-6.
[25] Nightingale C and Jones S P 2003 A clinical investigation of force delivery systems for orthodontic space closure. *J. Orthod.* **30** 229-36.
[26] Kapur R, Sinha P K and Nanda R S 1998 Frictional resistance of the Damon SL bracket. *J. Clin. Orthod.* **32** 485-9.
[27] Tripolt H, Burstone C J, Bantleon P and Manschiebel W 1999 Force characteristics of neckel-titanium tention coil spring. *Am. J. Orthod. Dentofacial Orthop*. **15** 489-507.
[28] Vidoni G, Pernetti G, Antoniolli F, Castaldo A and Camtardo L 2010 Combined aging effects of strain and thermocycling on unloading deflection modes nickel-titanium closed-coil springs: an in-vitro comparative study. *Am. J. Orthod. Dentofacial Orthop*. **138** 451-7.
[29] Misbah S, Bashir U, Rasool G, Arshad N, Asrar S 2008 Canine retraction: efficacy of methods applied over the years – A systematic review. *Pak. Oral Dent J*. **28** 175-80.