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Passive self-ligating brackets vs. conventional brackets: Is there a difference in the transverse dimension? A systematic review and meta-analysis

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Passive self-ligating brackets vs. conventional brackets: Is there a difference in the transverse dimension? A systematic review and meta-analysis

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ABSTRACT

SELF-LIGATING BRACKETS VS. CONVENTIONAL BRACKETS IN ORTHODONTICS: IS THERE A DIFFERENCE IN THE TRANSVERSE DIMENSION? A SYSTEMATIC REVIEW AND META-ANALYSIS

Justin TenBrook, D.M.D.

Background and Objectives:
Self-ligating brackets have risen in popularity in clinical orthodontics, but many claims made by their manufacturers have been made without substantial evidence. Any differences among the bracket types are very small when consulting new peer reviewed literature testing their differences. Nevertheless, self-ligating brackets are still purported to be able to increase the dental transverse dimension more effectively than conventional brackets. In 2018, Yang et al. performed a systematic review on the transversal changes, space closure, and efficiency of conventional and self-ligating appliances. Since then, there were several clinical trials published in the literature comparing the mandibular arch dimensional changes between these two types of brackets. The purpose of this systematic review was to include the new studies to give more practical advice on bracket selection in contemporary orthodontic practice.

Methods: This systematic review was conducted similarly to the Yang et al (2018) systematic review. An extensive systematic search of the most recent literature published after December 2016 to April 2022 was carried out to compare passive self-ligating brackets with conventional brackets in treating the transverse dental dimension. Randomized controlled trials only were included after systematically hand searching the PubMed literature database with the search terms: “passive” “self-ligating” “brackets” “conventional” “transverse” “orthodontics” respectively. Each article that met inclusion criteria was reviewed by a statistician to confirm heterogeneity and for potential meta-analyses.

Results: Out of 19 papers initially screened by abstract, 11 were included in this systematic review, with 6 being new articles having been published in the last 5 years. 2 were included with 4 articles were included in a previously published meta-analysis review to synthesize their results. Meta-analyses showed that passive self-ligating brackets increased intermolar width more than conventional brackets (0.59mm; $p = 0.0008$), while conventional preadjusted brackets increased intercanine width more than passive self-ligating brackets (0.42mm; $p = 0.007$)

Conclusions: The systematic review found 6 studies out of 19 to be included in a qualitative systematic review. From these six, 2 were included in a meta-analysis including 4 studies used in the previous systematic review. Passive self-ligating brackets expanded the mandibular intermolar width slightly more than conventional brackets, and conventional preadjusted brackets expanded intercanine width slightly more than passive self-ligating brackets, both being statistically significant respectively. High heterogeneity in the intercanine measurements calls these results into question. The difference in width increases between the bracket types were deemed not clinically significant. Future research should standardize arch forms and wire sequences to further differentiate between the two bracket types.

DEDICATION

To my parents, **Mom and Dad**: I would not be a dentist nor orthodontist without your continued guidance and steadfast support. You both have been invaluable and priceless resources and I am forever grateful for both of you.

To my wife, **Mariam**: Thank you for your boundless love and support through my residency, research**,** and writing this thesis. Your patience and kindness never go unnoticed, and I could not have done it without you.

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CHAPTER 1: INTRODUCTION

BACKGROUND and SIGNIFICANCE

The orthodontic world loses its credibility when erroneous claims are made about appliances that are not backed by scientific evidence. New products and technologies should be extensively scrutinized with evidence-based research so orthodontists can make the best treatment choices for their patients. It unfortunate that Key Opinion Leaders, orthodontists, and orthodontic appliance manufacturers often make bold claims to influence the opinions of both the general public and orthodontic professionals alike. Often, the statements made may reflect a singular orthodontist's own clinical experience with a certain appliance that works well in his or her hands, rather than something that can be definitively said as a fact. With only financial gain in mind, companies may push a new product that is not too special under scientific scrutiny. One of the more controversial products in modern orthodontics is the self-ligating bracket and its claimed benefits over conventional orthodontic brackets.

Evidence supporting the use of self-ligating brackets is questionable at best, and many other systematic reviews have concluded there not being much difference between the two types. One major feature or proposed benefit of passive self-ligating brackets in particular is the idea that superior dental expansion occurs when combining the self-ligating brackets with oversized archwires. Expanding the dental arches in such a way would provide a wider, more esthetic smile, without compromising the biologic integrity of the periodontium. While the basis of "growing bone" may not be supported in any way by literature, many randomized clinical trials testing differences in passive self-ligating brackets and conventional preadjusted brackets in expanding the dental transverse dimensions have had conflicting results. More evidence was needed in the 2018 systematic review published by Yang et al concerning transverse dental changes between the two bracket types.

STATEMENT OF THE PROBLEM

Inconsistent information and claims exist in the orthodontic world and marketplace surrounding passive self-ligating brackets. One of its biggest claims concerning transverse dental changes has conflicting evidence from previous research.

PURPOSE OF THE STUDY

1. To better understand and differentiate between any clinical differences between passive self-ligating brackets and conventional preadjusted brackets in their treating the dental transverse dimension by searching recent peer-reviewed literature
2. To conduct a systematic review of all relevant literature to provide clinical guidance to practicing orthodontists concerning bracket selection in modern orthodontic practices

NULL HYPOTHESES

1. There is no significant difference between passive self-ligating brackets and conventional brackets in expanding the intermolar dental transverse dimension in mandibular arches
2. There is no significant difference between passive self-ligating brackets and conventional brackets in expanding the intercanine dental transverse dimension in mandibular arches

ALTERNATIVE HYPOTHESIS

1. Passive self-ligating brackets significantly expand the intermolar dental transverse dimension in mandibular arches more than conventional brackets.
2. Passive self-ligating brackets significantly expand the intercanine dental transverse dimension in mandibular arches more than conventional brackets.

ASSUMPTIONS

1. The systematic search protocol did not miss any relevant peer-reviewed study that met inclusion criteria
2. The studies had significant findings whether in either brackets' favor in terms of superiority

LIMITATIONS

1. Databases other than Pubmed were not searched
2. Heterogenicity of papers was not consistent
3. Not all papers that could have met the inclusion criteria were able to be accessed

KEY TERMS

1. Self-ligating brackets
2. Passive self-ligating brackets
3. Active self-ligating brackets
4. Intercanine width
5. Intermolar width
6. Arch form

7. Bracket slot

8. Transverse dental expansion

CHAPTER 2: REVIEW OF THE LITERATURE

History and Rationale of Self-Ligating Brackets

The first bracket with a self-ligating mechanism was described by Dr. Stolzenberg DDS in Brooklyn, New York in 1935. The design used a key and threaded nut to secure an arch wire into the slot of the attachment bonded to the teeth. Dr. Stolzenberg claimed Russell Attachments or Russell Locks permitted a more efficient mechanism for tooth movement. (Stolzenberg 1935). 90 years ago clinicians were seeking a more efficient way to ligate a wire to an orthodontic bracket, for at the time, the only way was using steel ligature ties. The desires of an orthodontist have not changed much in terms of wanting the most efficient treatment possible for patients.

Over time, orthodontic treatment in general became advanced in terms of pre-adjusted brackets, adhesive technologies, and new alloys for orthodontic arch wires, while self-ligating brackets were mostly forgotten until later. Firstly, the advent of bonding brackets to teeth was invaluable for efficiency. No more were separating each interproximal tooth contact with elastomeric wedges or wires, band fitting, nor excessive cement cleanup necessary. The first bonding adhesive was introduced in 1970, with more advances continuing into the 80s, 90s and 00s (Sofan 2017). The straight wire appliance with preadjusted brackets prescriptions specific for each tooth was developed in the 1970s by Dr. Larry Andrews (Andrews 1975). Preadjusted brackets made most wire bending that was required previously obsolete and almost unnecessary, depending on the orthodontic philosophy one may subscribe to. By the 1990s most orthodontic brackets were bonded onto tooth surfaces with bands sparingly used for molars, and wire bends were only routinely needed for finishing stages. It was around this time that Dr. Dwight Damon’s self-ligating bracket technique gained popularity. For as many other facets of dental and orthodontic world had changed for the sake of efficiency, why not the orthodontic bracket ligation system as well?

Orthodontic treatment truly had come a long way since the 1930s, but orthodontists were still looking for more efficient treatment modalities as the twentieth century progressed. A significant period of time elapsed until the next iterations of self-ligating brackets hit the market. A big reason there was a delay in the wide production and availability of self-ligating brackets may have been the development of elastomeric ties in the 1960s. After the Russell attachment, the next bracket major self-ligating bracket iteration was the Edgelok bracket in 1972, followed by the SPEED bracket in 1980. (Harradine) In coordination with Dr. Andrews Straight Wire appliance, many designs have come and gone with the development of pre-adjusted edgewise bracket systems and more modern superelastic and nickel-titanium wires becoming popular and nearly commonplace. It wasn't until the 1990s when Dr. Dwight Damon shined the spotlight on self-ligating brackets and demanded the attention of the orthodontic community with the development of his own self-ligating bracket and treatment philosophy.

Dr. Damon claimed passive self-ligation provided more biologically appropriate physiological tooth movement in his seminal paper describing his new passive self-ligating bracket (Damon 1998). He claimed that it was the challenge of the orthodontist to overcome "suffocating" the periodontal ligament that occurred frequently with conventional orthodontics. By allowing the teeth to align with light forces, clinicians would no longer have to "overpower the facial musculature" and overcome elastic or ligation friction by increasing archwire forces. In addition, Dr. Damon claimed passive self-ligating brackets increased torque control, prevented flaring of the incisors, could experience true sliding mechanics, had minimal friction, reduced chairside time for clinicians, reduced patient discomfort, and even reduced overhead (Damon

1998). One could consider these claims published in peer-reviewed literature as the catalyst that propelled passive self-ligating brackets into the spotlight. For if the claims made about the brackets were true, who could deny their benefit over conventional brackets? Many would come to question the proposed effects of the Damon brackets.

Evolution of Bracket Design—The Ideal Orthodontic Bracket

Although the benefits of self-ligating brackets are debated among orthodontists themselves, there are some accepted hypothetical qualities that apply when one thinks of the ideal orthodontic bracket. Harradine described such qualities of the ideal bracket system including: secure ligation of wire into brackets (which translates into less emergency visits for patients), full engagement of wire into bracket slot (more control of tooth movement), low friction between wire and bracket slot, easy to use by orthodontist and assistants, allow for good oral hygiene, and be comfortable for the patient. It is difficult to have all these qualities in one orthodontic bracket, and thus the perfect orthodontic bracket does not exist.

Elastomeric modules experience significant force decay over time. In fact, it has shown that over the first twenty-four hours of placement, elastomeric ligature ties lose over fifty percent of their strength, and up to 68% depending on the brand of tie (Taoumis 1997). Although not an issue for levelling and aligning, rotational control and torque expression could be compromised if a patient misses their appointment, or if robust engagement was required for en masse tooth movement, to give a couple of examples. Full engagement of the wire into the slot would provide the orthodontist with as much control as possible over the tooth movement. When an elastomeric tie loses its strength, it could be inferred that the wire could move out of its seated position and tooth movement and position could be compromised. To overcome the decrease in strength of the elastomeric tie over time, one could tie the elastomeric ligature tightly in a figure-eight fashion, but this would inherently increase friction. Thus, a bracket that could decrease friction between the wire, ligature and bracket itself would decrease the total force needed to move the teeth which would lead to many benefits. One could instead use steel ligature ties, but they have largely been removed from orthodontic practice because of their time-consuming nature to employ. It was the lack of efficiency of steel ligature tying that lead to the development of elastomeric ligature ties in the first place (Harradine 2008).

Evolution of Bracket Design—Active vs passive

Self-ligating brackets generally have mechanisms that close over the bracket slot like a door or slide, essentially forming a tube which the moving apparatus becoming the fourth wall. The first self-ligating bracket, the Russell lock, used a different kind of screw mechanism, but most all others developed since have a door mechanism that closes, usually in a vertical manner. Some self-ligating brackets have a door that forcefully holds the wire down into the slot of the bracket, termed active self-ligating brackets. Other self-ligating brackets have a door that closes and allows the wire to freely exist in the slot without additional pressure, termed passive. Thus, in passive self-ligating brackets, when wires are used at a size smaller than the slot size, slop or free space will exist allowing some play in the way the wire contacts the slot walls, potentially minimizing friction.

Previous Research and Current Evidence

While early systematic reviews supported the basis that SLBs may have a benefit over CBs in term of clinical efficiency with round wires, more recent studies written over the past decade have muddied the waters. Newer studies, including multiple systematic reviews, have almost unanimously have ruled out any clinical benefit of SLBs compared to CBs. Indeed, many authors claimed that one bracket type cannot be shown to be better or worse than the other However, some studies state that initial alignment and perceived pain may be areas where SLBs outshine CBs, but yet again, more research is needed in the area. Common among many published articles concerning self-ligating brackets, it has been concluded that more research is needed in the area to be able to make more definitive statements concerning advantages or disadvantages of bracket types. The main issue in comparing many of the studies is the differences in methodology and thus high heterogeneity between them.

A significant number of systematic reviews published over the last ten years have tried to elucidate concrete data to distinguish between conventionally ligated and self-ligated brackets. Many have found inconclusive data (Fleming 2010, Chen 2010, Celar 2012, Nascimento 2013, These studies focused on many variables at the same time, but mostly were concerned about efficiency of treatment with either bracket type. One of the main findings was it may be faster to insert a 19x25ss wire into the lower arch with self-ligating brackets, truly one of only a handful of other variables found to be insignificant.

True, minor differences between the bracket types have been found in some research. In a systematic review which studied the difference in external root resorption in patients treated with conventional or self-ligating brackets, self-ligating brackets caused significantly less external apical root resorption when compared to conventional brackets (Yi 2016). Note, this was only referring to the maxillary central incisor. The systematic review found out that any other differences were not significant for any other teeth studied, the maxillary lateral incisors, mandibular central and mandibular lateral incisors, respectively. Another systematic review (Al-

Thomali 2017) determined that conventional brackets expressed the most torque compared to active and passive self-ligating brackets, however all the studies used were in vitro. It is difficult to ascertain the importance of in vitro studies because their results cannot be guaranteed to be applicable to a clinical setting.

In vitro studies

While randomized controlled trials and other clinical studies have conflicting evidence in terms of one bracket type's superiority, in vitro studies have shown in general that self-ligating brackets will produce less friction than conventional brackets in the laboratory setting. Concerning friction, multiple studies included in a systematic review comparing in vitro studies concluded that self-ligating brackets produced lower friction when used with small diameter round wires. The authors noted that there was a controversy when rectangular wires were used in various studies with conflicting results. The systematic review claimed that in general, increasing wire size in either bracket type would increase friction. This difference is minimal when rectangular wires are used but small diameter round wires will produce less friction.

Another systematic review published in 2010 compared the difference in torque expression in orthodontic stainless steel conventional brackets and between active and passive self-ligating brackets separately. All studies included were in vitro, and it was found that engagement or deviation angle differences were highly variable between all bracket types, suggesting that the reliability of bracket manufacturer's claims is limited even in terms of slots size regularity. They did not compare conventional to self-ligating brackets directly. However, for 0.019 x 0.025 stainless steel arch wires in 0.022 x 0.028 slot size, active stainless steel self-ligating brackets had a smaller engagement angle of 7.5 degrees versus 14 degrees for passive self-ligating brackets. This suggests that active self-ligating brackets had better torque expression than passive self-ligating brackets. One must note that this in vitro study was highly controlled and no second order movements were at play, something that almost certainly occurs in the in vivo or clinical setting.

Beyond passive versus active brackets, another in vitro study showed that friction increased with the presence of saliva and increased temperature. Another interesting variable was the bracket slot bevel, which decreased friction the higher the bevel angle (Chang). The in vivo study used artificial saliva, and suggested although there were differences, they may be minimal in a clinical setting.

It has been well shown that wire alloy makes a difference in friction as well. Specifically, beta-titanium or titanium-molybdenum alloy has the highest frictional forces during sliding mechanics, followed by nickel titanium and then stainless steel. (Proffit). Another way to think about it is that friction will increase proportionally to the amount of titanium present in orthodontic wires (Proffit).

Research Concerning Transverse Dimension

One area where evidence is not generally lacking, but where evidence is conflicting among studies is the area of dental transverse expansion. A proponent of the Damon treatment philosophy and treatment protocol is the use of an extra-broad arch form in conjunction with passive self-ligating brackets. Many have claimed that the wider arch form allows for arch development, or expansion of the arch to accommodate crowding, without losing incisor control. The reason this is possible is due to the lack of friction between the archwires and brackets, or at least is what is claimed.

The most recent systematic review on the subject of dental transverse dimension comparing self-ligating brackets to conventional brackets was conducted by Yang et al (2018) which found 6 different papers and included 4 in a meta-analysis comparing passive self-ligating brackets to conventional brackets in expanding the mandibular dental arches, with the intercanine and intermolar widths beings the major data points. Their meta-analysis concluded that conventional brackets caused more expansion of mandibular intercanine width, whereas passive self-ligating brackets more effectively expanded mandibular intermolar width. The authors noted that the sample size was small, risk of bias was unclear, and methodology between the studies showed high heterogeneity. A sensitivity analysis further noted that any differences between passive self-ligating brackets and conventional brackets in expanding the mandibular intermolar width was insignificant. More research into the subject of dental expansion effectiveness between bracket types was noted. Since the Yang 2018 systematic review, 5 more controlled clinical trials have been conducted and have not been synthesized into one review. This systematic review will analyze the new studies since Yang 2018 and attempt to synthesize their results. Many of the studies will be further discussed in discussion section.

CHAPTER 3: MATERIALS AND METHODS

IRB Approval

An application for IRB approval was submitted to the West Virginia University Institutional Review Board for approval prior to the initiation of the study. The WVU IRB concluded that IRB approval was not necessary due to the nature of the systematic review and data collection.

Systematic Review Design

This systematic review was conducted similarly to the Yang et al (2018) systematic review. It looked at the most recent literature published since the named systematic review, after December 2016 to April 2022, to compare passive self-ligating brackets with conventional brackets in treating the transverse dental dimension. Randomized controlled trials were included after hand searching the PubMed literature database. Inclusion and exclusion criteria are described below. Each article was reviewed by a statistician to confirm heterogeneity and for potential meta-analyses. The statistician had the final say in which studies could be included in the meta-analysis. Studies with high i^2 values needed subgroup analyses performed to test heterogeneity.

Inclusion criteria included: only randomized controlled trials (RCTs), patients in experimental/intervention group treated with passive self-ligating brackets, patients in control groups having conventional preadjusted brackets, clinical outcomes or results concerned arch transverse dimension intermolar and intercanine width expansion values in millimeters. All studies included in the systematic review used pre- and post-treatment models to make intermolar, and canine width changes, as well as pre- and post- ceph measurements for incisor inclination. Since not every study measured interpremolar distances, this data point was not included in this review.

Exclusion criteria included any split mouth studies, studies using active self-ligating brackets, studies using interactive brackets (partially passive, partially active depending on wire used), studies with patients undergoing extraction treatment, studies with repetitive data, in vitro studies, animal studies, and patients included in studies with any health conditions that could affect orthodontic treatment, as well as studies with patients in which the full orthodontic arch was not treated

The systematic review found 6 peer-reviewed studies when the Pubmed database was hand-searched using the search terms: “passive” “self-ligating” “brackets” “conventional” “transverse” “orthodontics”. From the 6 studies, 2 were narrowed down when analyzing each methodology, and when applying constraints made by inclusion and exclusion criteria mentioned above. Only two were included in the meta-analysis based on the statistician’s judgement. A comparison of the 4 new articles not included in the meta-analysis but published after Yang 2018 follows in the discussion section.

Studies that included active self-ligating brackets were included but the data concerning active brackets were not included because it was assumed they inherently would add friction in a similar manner to steel ligature ties or figure 8 elastomeric ties. In addition, many studies comparing active and passive self-ligating brackets have found no significant differences between the two.

Studies were first analyzed by their abstracts. Studies were not included based on abstracts if they were not randomized control trials, if they were split mouth studies, or were in vitro studies. Once confirmed that they could be potentially used for the systematic review and passed the abstract proxy, they were analyzed under the following criteria: patients were treated non-extraction, passive self-ligating brackets were compared to conventional preadjusted brackets, intermolar and intercanine widths were measured before and after treatment (or after alignment), ETC. Studies that used differing arch forms and wire sequences were at first planned to not be included in this systematic review but since there were no new studies published after 2017 using the same exact wire sequence and arch forms, they were included. From NUMBER of studies initially found using the search terms “passive self-ligating,” “conventional,” “transverse,” and “orthodontic bracket.”

CHAPTER 4: RESULTS

A total of 19 published articles were initially identified by title from the electronic search of the Pubmed database using the specific search parameters, 11 of which were considered eligible and they were analyzed thoroughly after being screened by their abstracts. From these, 6 were included in the qualitative review of articles having been published after the Yang 2018 systematic review, with two meeting requirements for the quantitative meta-analysis. These final two were combined with the 4 from the previous systematic review for the meta-analysis as described in the methods section.

The data was collected and is shown below in two Forrest plots. Standardized mean differences were plotted with confidence intervals, and line of no effect was set at 0. Any study which confidence interval crossed the line of no effect was individually considered nonsignificant due to the nature of the Forrest plots and the data collection. Any study that did not cross the line of no effect was individually deemed as significant. The wider the confidence intervals, the less the precision of the studies included in the meta-analyses.

Figure 1 shows the meta-analysis performed for mandibular intermolar width change between passive self-ligating brackets and conventional brackets. 155 patients were treated with passive self-ligating brackets while 153 were treated with conventional brackets between the 6 published studies. The data trended "in favor" of conventional brackets, however this wording is not indicative of the actual results due to the nature of the statistical workup: More intermolar width change was seen in self-ligating brackets, with the results being statistically significant. Since passive self-ligating brackets were group one in the data, a positive value for the difference of the means would indicate in fact that more change in dental transverse width occurred for the first group. The null hypothesis was thus rejected, with there being a modest yet statistically significant difference in mandibular intermolar width change between the two bracket types (0.59mm; p = 0.0008). Figure 1 also shows a small i^2 of 11% for intermolar width, meaning low heterogeneity was found for the data concerning mandibular intermolar width.

Study or Subgroup	PSLB Mean	PSLB SD	PSLB Total	CB Mean	CB SD	CB Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Pandis 2007	2.04	1.6	27	1.23	1.57	27	16.7%	0.81 [-0.04, 1.66]	2007
Scott 2008	0.09	2.4	32	0.63	2.12	28	9.1%	-0.54 [-1.68, 0.60]	2008
Flaming 2009	1.41	1.7	29	0.5	1.44	31	18.7%	0.91 [0.11, 1.71]	2009
Pandis 2011	1.9	1.3	25	1.5	0.9	25	31.2%	0.40 [-0.22, 1.02]	2011
Mateu 2018	-0.09	1.45	12	-1.07	1.65	12	7.7%	0.98 [-0.26, 2.22]	2018
Esteves 2019	1.66	1.58	30	0.86	1.78	30	16.5%	0.80 [-0.05, 1.65]	2019
Total (95% CI)			**155**			**153**	**100.0%**	**0.59 [0.24, 0.93]**	

Heterogeneity: Chi² = 5.60, df = 5 (P = 0.35); I² = 11%
Test for overall effect: Z = 3.34 (P = 0.0008)

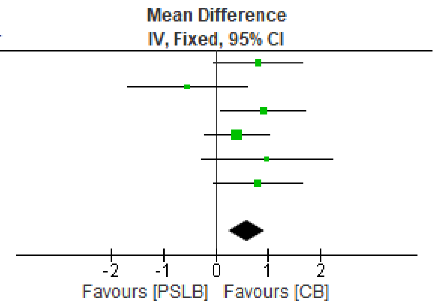

Figure 1 Meta-analysis of mandibular intermolar width change of passive self-ligating brackets (PSLB) and conventional brackets (CB). 95% CI=95% confidence interval, SD=standard deviation

Figure 2 shows the meta-analysis performed for mandibular intercanine width change between passive self-ligating brackets and conventional brackets. The same 155 patients treated with passive self-ligating brackets, and 153 patients treated with conventional brackets between the 6 studies were included. The data trended "in favor" of passive self-ligating brackets (PSLBs), but again this wording was not ideal. More mandibular intercanine width change was seen in conventional brackets, with the results being statistically significant ($p = 0.007$). The null hypothesis concerning intercanine width was also rejected, with there being a modest yet statistically significant difference in mandibular intercanine width change between the two bracket types (0.42mm). Compared to the intermolar variables, the i^2 of 65% for intercanine measurements does indicate high heterogeneity between the data points.

Study or Subgroup	PSLB Mean	PSLB SD	PSLB Total	CB Mean	CB SD	CB Total	Weight	Mean Difference IV, Fixed, 95% CI	Year
Pandis 2007	1.08	1.17	27	1.58	0.9	27	30.4%	-0.50 [-1.06, 0.06]	2007
Scott 2008	2.55	2.27	32	2.66	2.33	28	6.9%	-0.11 [-1.28, 1.06]	2008
Flaming 2009	0.85	1.52	29	1.17	1.77	31	13.6%	-0.32 [-1.15, 0.51]	2009
Pandis 2011	1.4	0.8	25	2.1	1.2	25	29.5%	-0.70 [-1.27, -0.13]	2011
Mateu 2018	0.42	1.64	12	1.9	0.92	12	8.3%	-1.48 [-2.54, -0.42]	2018
Esteves 2019	1.33	2.18	30	0.34	1.32	30	11.3%	0.99 [0.08, 1.90]	2019
Total (95% CI)			**155**			**153**	**100.0%**	**-0.42 [-0.73, -0.11]**	

Heterogeneity: $Chi^2 = 14.34$, df = 5 (P = 0.01); $I^2 = 65\%$
Test for overall effect: Z = 2.68 (P = 0.007)

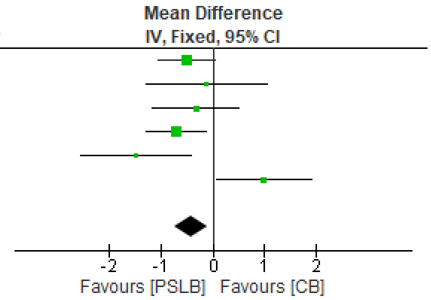

Figure 2 Meta-analysis of mandibular intercanine width change of passive self-ligating brackets (PSLB) and conventional brackets (CB). 95% CI=95% confidence interval, SD=standard deviation

Although there were statistically significant differences in intermolar expansion (favoring passive self-ligating brackets) and intercanine expansion (favoring conventional pre-adjusted brackets), the clinical significance was considered low if not insignificant clinically.

CHAPTER 5: DISCUSSION

The results from the meta-analyses showed there was significant differences between passive self-ligating brackets and conventional preadjusted brackets in the 6 included studies. Passive self-ligating brackets expanded intermolar widths more effectively, while conventional preadjusted brackets were able to expand the intercanine width more effectively. i^2 tests showed differences between intermolar and intercanine variables, with conventional brackets out-performing passive self-ligating brackets in expanding the intercanine width. However, differences in intercanine widths for pre- and post-treatment measurements would be found to be insignificant when subgroup analysis was performed.

The biggest confounding factors that make results questionable with the 2 new studies is the fact that the conventional bracket groups and self-ligating bracket groups both used different arch forms and wire sequences. Thus, certain studies may have been comparing the treatment effects of two different wire systems rather than the two bracket types. It is hard to say whether any significant differences that exist could be due to the brackets or the wire types in these studies. However, many orthodontists use these brackets with their respective recommended arch forms, as it is assumed that it would be rare for a passive self-ligating bracket using orthodontist to use normal arch form wires during levelling and aligning and vice versa. The data was collected and analyzed with these differences in wire protocols in mind. Similar to the systematic review done by Yang et al in 2017, studies were included that had different wire protocols between groups so it was accepted in our study as well as a compromise. In addition, treatment plans significantly differed between some papers that were finally included in the meta-analysis.

Two recent publications were included in the meta-analysis with the four original papers included comparing the transverse dimension in Yang 2017. Esteves et al (2019) compared two different brackets using different wire arch forms, similar to the methods of the Atik et al (2018) study. This randomized clinical trial had two groups, one receiving treatment with passive SL brackets (group 1; Damon Mx or Damon Q), the other with conventional preadjusted twin brackets (group two; Andrews straight wire). The authors were considerate of the biologic limits of expansion of the mandibular arch and used the WALA ridge as their reference, an acronym named after Dr. Will and Larry Andrews, the latter who first described this landmark for the width of the mandibular arch. The mandibular WALA ridge represents the limit of transverse expansion, and part of the Andrews Six Elements treatment philosophy which claims that the teeth should be upright over basal bone, using the bony landmark as the ideal width of the archwire or archform which when engaged would center the teeth over the basal bone. This landmark was used for group 2 for the placement of their passive stainless steel final wires sized 0.019 x 0.025 stainless steel, while group one had Damon broad arch forms from the first wire, and the passive stainless steel wire was formed to the arch from a wax bite after the teeth had been previously expanded. Specifically, the group one wire sequence was: 0.014” Cu-NiTi, 0.014 x 0.025” Cu-NiTi, 0.018 x 0.025” Cu-NiTi, 0.017 x 0.025” TMA, and 0.019 x 0.025” stainless steel. The archform diagram was made after levelling and aligning with the 0.014 x 0.025” Cu-NiTi wires. Contrasting this, the wire sequence for group 2 was 0.014” NiTi, 0.016” NiTi, 0.018” NiTi, 0.020” NiTi, and finally 0.019 x 0.025” stainless steel. Instead of using the archform after levelling and aligning to shape the final passive stainless steel wires like in group 1, the passive final stainless steel arch forms for group 2 were made off the WALA ridge landmark from the initial pre-treatment casts for each patient. Thus the two groups in a way represented two different treatment philosophies, and made comparing the bracket types in this systematic review difficult. They measured intercanine, interpremolar, intermolar widths, and

WALA ridge width associated with the same teeth respectively before and after treatment. The methodology was considered similar enough by the statistician to be used for the meta-analysis in this systematic review.

The results showed that group 1 experienced arch expansion at premolars and molars only, with no significant difference between canines and WALA ridge. Group 2 unsurprisingly experienced arch expansion at every measured variable including the WALA ridge itself. The authors noted that the arch expansion occurred mostly in the premolar region via buccal tipping. As mentioned earlier, this study used different methods of treatment and thus its inclusion in the meta-analysis is not without considering these differences in treatment modalities. Its conclusion confirmed many suspicions that expanding the dental arches is indeed possible and may violate anatomical boundaries. It is interesting that the WALA ridge itself moved with the teeth, which could not only remove this study from serious scrutiny because not all use the landmark to measure skeletal width, but also call into question the reliability of the WALA ridge as it could change throughout treatment. Then again, using the bony reference with pre-treatment models could remove the worry of changing the anatomical boundaries of the lateral alveolus, which could in theory cause instability of the orthodontic treatment results if violated.

Since the Yang 2016 systematic review, five papers were found that had similar study design. The four listed below were not included because of high heterogeneity found when comparing them with (this statistical test) and for their broadly different study designs. The biggest issue when comparing these studies was the differences in wire progression and arch forms used by the various clinicians. They will be described below so that no confusion could arise when comparing results. Since meta analysis of the described papers below was not possible, this discussion should be taken with a grain of salt.

First is Atik 2018, a retrospective study in which the pre-treatment and post-treatment dental models of patients treated with either active self-ligating brackets (Damon; group 1), interactive SL brackets (American Orthodontics Empower; group 2), or conventional preadjusted brackets (Forestadent; group 3) were analyzed. All patients were teenagers with permanent dentition with moderate mandibular crowding and were treated non-extraction. Each group received the same size arch wires but not the same arch forms, a major reason for its non-inclusion in the meta-analysis. Group 1 was treated with Damon broad arch forms, while groups 2 and 3 had normal Ormco arch forms (shape was not specified). Group 3 had all brackets tied in with steel ligatures. The wire sequence regardless of arch form was the following for each group: 0.014-inch, 0.018-inch, 0.017 x 0.025-inch Cu-NiTi, followed by 0.017 x 0.025-inch, and finally 0.019 x 0.025-inch stainless steel. Pre-treatment and post-treatment dental models were used to measure intercanine, inter-first-premolar, inter-second-premolar, and intermolar widths. Pre-treatment and post-treatment cephalometric values for lower incisor inclination and anterior-posterior position were also measured. The purpose of the study was to compare the treatment effects of different brackets and wire protocols and their effect on arch width and lower incisor position. The results showed that there was no significant difference between either of the three groups. Arch widths were similar and mandibular incisors proclined in each group. The authors did note however that arch length increased the most in the Damon active SL group, which was statistically significant. Overall, the differences are questionable at best. It was noted that the broad arch form wires did not result in statistically significant differences. It would have been prudent if the authors included passive SL brackets with broad wires. Since the null hypothesis of this present review was to study passive self-ligation, this study was also removed for consideration for this reason. While the group 2 self-termed "interactive" brackets may act like passive self-ligating brackets with small round wires, they essentially become active once rectangular arch wires are used.

Next was Bashir 2019, a nonblinded randomized clinical trial similar to Atik 2018 in which pre-treatment and post-treatment dental models of patients treated with either conventional preadjusted brackets (3M; group 1), passive SL brackets (3M Smartclip; group 2) and active SL brackets (American Empower; group 3) were analyzed. Each group had 14 patients aged between 16-25 with bimaxillary protrusion and all were treated with all maxillary and mandibular first premolar extractions. It was confirmed before the study commenced that each patient had passed their peak pubertal growth spurt, thus not much growth potential remained. Because the goal of this paper was to determine the effects of brackets on treatment, the same wire sequence and arch forms were used between all three groups. The sequence of wires was 0.014" NiTi, 0.016" NiTi, 0.017 x 0.025" NiTi, 0.019 x 0.025 NiTi and 0.019 x 0.025 stainless steel. First premolar extraction spaces were carried out on the final stainless steel wires using NiTi coils. No other appliances or auxiliaries were used for any patient. They measured intermolar and intercanine widths only from pre-treatment dental models, and dental models taken after 6 months of space closure. They did not compare cephalometric values, and only were concerned with canine and first molar width changes. For all three groups there was a statistically significant increase of arch width at canines and first molars, but both groups with active and passive SL brackets experienced more dental width gains. The passive SL bracket group experienced the most arch width gain between the three groups. The authors argued that testing the three bracket types in first premolar extraction treatment would minimize arch expansion by tipping. One could argue that distalizing canines into a wider portion of the alveolus could explain the expansion achieved, but it must be noted that passive SL brackets caused the greatest amount of expansion, and this was statistically significant. Since the current review did not consider studies with patients undergoing extraction treatment, this paper was not included in the final review. This was the only study that maintained arch forms between all three groups, and thus is in favor of passive self-ligation for more dental expansion. Whether more is a good thing or not depends on the orthodontic diagnosis and treatment plan; it is possible that one would not want any more buccal tipping or expansion, or vice versa, depending on the initial inclination of posterior teeth. For example, this study suggests that for patients with dentally constricted arch forms with normal skeletal widths, using passive self-ligating brackets may influence the most effective uprighting of those teeth. Conversely, this study suggests that teeth that already slightly buccally inclined and in need for their inclination maintained may benefit from treatment with conventional preadjusted brackets, to minimize any further expansion or buccal tipping that may occur.

Comparing Bashir and Atik's papers show the challenge in a systematic review using studies with different designs. It is noted that Bashir et al. considered American Orthodontics Empower brackets as purely active, while Atik et al. considered them "interactive." It is true that American Orthodontics itself as a bracket manufacturer claims that these specific brackets are not active until the wire size encroaches on the clip of the bracket. This semantic difference is small but confusing. Another major difference between Atik and Bashir was the ages of patients and exemplifies why comparing the results between the two studies is inherently difficult due to high heterogeneity. Atik 2018 had patients aged 13-18 thus growth could have affected result differences while Bashir 2019 had patients all after their growth spurts. Atik et al. did not standardize the wire arch forms between the group as well, while Bashir did. Atik also had nonextraction treatment plan in patients with mandibular crowding up to 6mm, while Bashir administered first bisuspid extraction treatment plans to compare the bracket types.

Moyano et al 2019 conducted a retrospective study comparing passive self-ligating brackets and conventional preadjusted brackets. Compared to the other new studies, this paper had a control group which had no orthodontic treatment to compare both SL and conventional groups. This study was also unique for its larger sample sizes in the experimental groups; 51 patients were in group 1 treated with passive self-ligating brackets and broad arch form wires from the start (Damon system; Ormco; Damon Rx), and 55 were in group 2 with arch forms customized to each patient (conventional preadjusted brackets; Omniarch; GAC-Dentsply; Roth Rx). Wire sequence for group 1 was 0.014" CuNiTi, 0.014 x 0.025" CuNiTi, 0.018 x 0.025" CuNiTi, 0.019 x 0.025" stainless steel, while the wire sequence for group 2 was 0.016" NiTi, 0.018" NiTi, 0.016 x 0.025" NiTi, 0.019 x 0.025" NiTi, and lastly 0.019 x 0.025" stainless steel. A smaller number of participants were included as a control group (group 3; untreated) who never received orthodontic treatment. These 20 study participants had orthodontic records taken at the start of the study and then another set taken 24 months later. All participants were from a pool of 300 consecutively treated patients from a single orthodontist. Maxillary and mandibular dental widths were measured for all posterior teeth (up to second molars) and canines, and cephalometric values of mandibular incisor to mandibular plane angle and mandibular distal molar angulation to mandibular plane. All patients were selected by having crowding up to 5mm, non-extraction treatment with no other auxiliaries. Results showed that between the two experimental groups, lower incisors proclined more with conventional brackets compared to self-ligating. Distal angulation increases only occurred in self-ligating groups and the differences were not significant for the other two groups. The difference in angulation could be due to bracket prescription differences, bonding errors, among other things and is not deemed significant by this review.

The most recently published study concerning SL vs CBs also was a split-mouth randomized clinical study in by Moradinejad (2021) which all patients had maxillary canine retraction after maxillary first premolar extractions. All maxillary teeth had conventional stainless steel preadjusted metal brackets (0.022 x 0.028" slot MBT), and either canines were replaced after levelling and aligning up to 0.018 NiTi arch wires and then extraction of maxillary first premolars. Both canines were replaced with either an active ceramic self-ligating bracket (Quicklear; Forestadent) or a conventional preadjusted ceramic bracket with metal slot. All other teeth with conventional preadjusted metal brackets were maintained on the other teeth. Canines were retracted on 0.018 stainless steel arch wires with 150g NiTi coil springs, with posterior teeth colligated with stainless steel wires. The conventional ceramic brackets were only ligated with elastomeric ties. Maxillary dental impressions were taken before treatment and after 3 months of canine retraction. The dental casts made from the impressions were scanned with a 3-shape-trios scanner and the digital files were analyzed for differences in arch dimensions between the two canine retraction methods. The authors noted the before and after models were aligned using palatal rugae for superimposition. They measured the transverse arch width between canines and second premolars only, and measured distance of canine distalization, anchorage loss, and amount of canine tipping and rotation.

Arch expansion at the canines was significant and nearly twice the amount on conventional bracket side of the arch. Conversely, premolar sites constriction between the two bracket types occurred in a similar fashion with no significant differences. Canines distalized twice as fast in the conventional ceramic bracket group, however the teeth experienced twice the amount of tipping and rotation. Anchorage loss was similar between both bracket types. Although distalization occurred faster with more arch expansion, it came at the expense of first and second order consequences for the retracted canines with conventional brackets. This study was not included in the final analysis due to the split-mouth study design. Only one bracket was different in the experimental group, and this was considered not sufficient to compare two brackets, for it is understood neighboring tooth positions, prescription and ligation type would exhibit different effects to their neighbors. Nevertheless, the study showed that self-ligating brackets may exhibit superior tooth control in distalization into an extraction space, at the expense of efficiency.

Future research concerning passive or active self-ligating brackets compared to conventional preadjusted brackets must employ the same wire sequence and arch forms. It defeats the purpose of comparing bracket types if different wires are used, and this should be more of a highlighted discrepancy of study design instead of being mentioned in one line in the methods section like many of the studies above. Many may read these studies and overlook this completely, that different wire sequences, or arch forms were used, among other differences that were noted above. The inherent differences between studies makes definitive conclusions almost impossible, even if the same variables were measured. Another variable that made comparing some studies difficult was the age of the patients in studies. Some included patients that were growing, and thus skeletal growth that occurred during treatment could have changed the results if patients had no growth remaining. It would be prudent to test the bracket types with patients who are not growing, with similar ages. It is well known that each patient has a different growth potential. A good sample could potentially include young adults that had finished growth and had no previous treatment. It would be interesting to have studies with such groups having non-extraction treatment, and extraction treatment, with the same wires and arch forms. It is essential for studies to have experimental and control groups undergo the exact same treatment, with the only difference being the bracket types. Even the bracket prescription between the self-ligating and conventional brackets should be the same. This was often not the case, in fact each study had different prescriptions between bracket type groups. It is also noted that such a "perfect" study design would be inherently difficult to control, and other differences between patients, such as bone density, attached tissue amounts, or others could confound results as well.

Here lies the crutch of the situation: when it comes to the state of peer-reviewed, evidence-based literature in the orthodontic space, published literature that exists on either side of many debates within the community. Does extraction treatment decrease facial esthetics over time? Is Invisalign treatment superior to fixed appliances? Do class II correctors grow the mandible? It is unfortunate that evidence is conflicting in each of these questions (although there opinions overall regarding these in the orthodontic world crystalized that represent the majority). In other words, one could find a study that backs up his or her opinion and run with it, while turning a blind eye to others that may contradict such an opinion or treatment philosophy. At the end of the day, each individual orthodontist must think critically and use their extensive clinical and academic training to come to an educated opinion on controversial topics in this field.

CHAPTER 6: SUMMARY AND CONCLUSIONS

The systematic review found 6 studies out of 19 to be included in a qualitative systematic review. From these six, 2 were included in a meta-analysis including 4 studies used in the previous sytematic review. Passive self-ligating brackets expanded the mandibular intermolar width slightly more than conventional brackets, and conventional preadjusted brackets expanded intercanine width slightly more than passive self-ligating brackets, both being statistically significant respectively. High heterogeneity in the intercanine measurements calls these results into question. Even if the studies had identical methodologies, the differences in width increases were deemed to not be clinically significant. Future research should standardize arch forms and wire sequences to further differentiate between the two bracket types.

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