Letters to the editor*

Biomechanics of self-ligating brackets

One of the hottest subjects in town is the difference between self-ligating and conventional brackets, especially from the biomechanical point of view.

We applaud the group from Edmonton, Alberta, Canada, for their impressive study in the October issue (Badawi HM, Toogood RW, Carey JPR, Heo G, Major PW. Three-dimensional orthodontic force measurements. Am J Orthod Dentofacial Orthop 2009;136:518-28).

However, we have several comments.

The loading procedure described in the study cannot be performed in vivo. Therefore, we believe that the meaning of the loading graph for the clinician is questionable. In a clinical situation, there are 2 main ways to place the wire in the malaligned canine. 1. Engage the wire in the neighboring teeth and later pull the engaged wire toward the canine; sometimes, using conventional brackets, binding and friction effects on both sides decrease the extrusive force applied to the tooth to zero. 2. Engage the teeth one after the other: first, the lateral incisor or the first premolar and then the canine, continuing to the next tooth. We believe that this would produce a different loading graph.

The article ignores that, immediately after about 0.5 to 1 mm of canine extrusion, the extrusive forces on the canine in the self-ligating bracket, as can be seen in the graph, are higher than in the conventional bracket. This means that, during most of the treatment time with self-ligating brackets, the canine is exposed to higher forces in this direction than with conventional brackets.

The time factor affects not only the elastomeric qualities of the ties, but also the whole force system. Unfortunately, the time factor in the study was not mentioned. The scale of the forces and moments in Figures 4 and 5 are different and might lead to mistakes because of some optical fixations.

The unloading forces of the conventional brackets in the Fx and Fy directions clear more room for the canine to move vertically and buccally. This might be an advantage in most patients when gaining space is required.

We believe that the measured moments and their depiction in the graphs need more in-depth analysis and explanation. The moments developed on each tooth have 2 sources. The first is the couple produced in the bracket, and the second is the force applied on the bracket from the wire multiplied by the distance to the center of resistance. For that matter, using a round wire, Mx (moments in the buccolingul direction) consists only from the moment generated by the force in that direction, multiplied by the distance to the center of resistance. My and Mz are the sum or the difference (depending on the direction) of the 2 above-mentioned moments. Unfortunately, we did not find in the article the distance from the bracket to the center of resistance in any of the 3 axes.

Most forces and moments on the lateral incisor and premolar are the result of binding and not friction. Using the same bracket, even with different methods of ligation, should not influence binding, and we found no notes related to binding in the article.

The sentence, "we would expect to see more vertical canine movement and less tipping of the adjacent teeth with passive ligation compared with conventional ligation," fits only this specific laboratorial mechanical system. Moreover, that conclusion involves the prediction of the biologic response. Since no theory regarding the response to force was proven correct, this assumption might be inappropriate.

We find it pretentious to describe the self-ligating force system as "more accurate," as mentioned in the conclusion section. The meaning of accuracy in the context of the article can easily be misunderstood and misused. From the article, we believe that a further conclusion might be that the results are an initial argument point to an ongoing discussion with a new and innovative tool.

Again, we praise the authors for their interesting and outstanding article.

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Authors' response

Thank you for this opportunity to reply to Dr Katz's letter, published in the January issue (Katz MI. Appearances count when industry underwrites research. Am J Orthod Dentofacial Orthop 2010;137:3-4), and to address the letter of Drs Brezniak, Proter, Herman, Turgman, and Zoizner.

"Leafing through" the October 2009 issue of the *AJO-DO* would definitely result in a distorted image of any article in that issue. We would have preferred to receive Dr Katz's concerns about potential bias in a study (due to research funds provided by industry), along with a discussion of the content in the article. We encourage him to critically read our article and give us his feedback about our method, data, and interpretation of the data.

We welcome academic scrutiny of our research efforts, which is a sign of scientific rigor. Because of the title of

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Dr Katz's letter, we feel obligated to explain that, until recently, our research was entirely funded by the McIntyre Memorial Research Fund, a trust fund available to the orthodontic department at the University of Alberta. It was established by a generous orthodontist who cared about the future of his specialty. The research conducted and published in the October issue was not funded by a private entity. We are glad that Dr Katz understands the need to go after industry funding for orthodontic research, something we had to do to continue the development of our research laboratory. We want to remind Dr Katz that passive self-ligation is not a bracket system belonging to 1 company; almost every orthodontic supplier has a passive self-ligation bracket system. Dr Katz incorrectly assumed that our experiments cannot be repeated; we welcome Dr Katz, his residents, and curious academics and clinicians to visit our research facility and spend time with us and our research assistant. The experiments can be easily repeated, and the method is not operator dependent. Finally, to answer Dr Katz's question: no, the financial support probably would not have been forthcoming from the company if the results had shown its product to be inferior. Dr Katz must decide for himself whether passive self-ligation (in vitro) produces a distinctly different force system than conventional ligation, or, on the other hand, he can believe that an orthodontic department program director (who decided not to use self-ligation in his private practice) with 2 mechanical engineering professors and a statistics professor conspired with a graduate PhD resident to produce evidence supporting self-ligation to acquire research funding in the form of student scholarships. We did not hide our relationship with industry and are proud that we attracted orthodontic research funds from corporations to continue developing our research. The alternative was to stop our research after the university funds ran out. We hope that Dr Katz and many others will agree that we made the right decision.

We thank Drs Brezniak et al for their critical appraisal of our article; they show a deep understanding of orthodontic biomechanical concepts. We will respond to their comments in order.

Their first point, regarding the loading procedure, is well made, and we recognize that in a clinical setting there are many ways to ligate a high canine, and each might produce a different loading curve. This is why we standardized our procedure and ligated the teeth in the passive position and then moved the canine into the displaced position before bringing it back to perfect alignment. When we designed our first experiment, we had to start with a well-controlled test that would allow similar conditions for both ligation methods; as Brezniak et al stated correctly, the sequence of ligation might affect the loading curve of conventional ligation more than self-ligation. We are replicating the same test by starting the canine in the default position and tying it first. Another reason that we wanted to test the loading and unloading curves was to investigate the effect of the ligation method on the superelastic behavior (difference between the loading and unloading curves in Fz) of nickel-titanium wires.

Their next comment, that extrusive forces on the canine are higher in the self-ligating bracket system, requires a correction. At about 0.5 mm of extrusion during unloading, the Fz with self-ligation is around 2.2 N, and, at about 1 mm, the Fz is around 1.9 N; with conventional ligation, the Fz values at the same extrusions (0.5 and 1 mm) are about 3.7 and 1.7 N, respectively. This pattern shows that with self-ligation the extrusive force drops from 4 to 2 N and is maintained at 2 N throughout unloading. Conventional ligation did not show the same consistent pattern as self-ligation.

Brezniak et al are correct in their statement that duration might be a factor affecting not just the elastomeric ties but the whole system, especially when we consider that degradation of elastics takes place in the oral environment. We mentioned that our in-vitro experiment does not replicate the oral environment; we intend to study the phenomenon of elastic degradation and its effect on the load-deflection curves of our experiment in the future.

Our intention for Figures 4 and 5 was to show the software display and user interface. With the software's ability to display the force system from more than 1 view, the scaling of the elastic ligation view and the passive self-ligation view are identical in each graph. However, we had to change the scaling and zoom out in Figure 4 when compared with Figure 5 to include the force vector in the screen capture frame.

Regarding the unloading forces of conventional brackets clearing more room for canine movement, we mentioned in our conclusion that "Based on those findings, we might not be able to make definite predictions on the effect of these differences on the actual tooth movements." We simply believe that, for vertically displaced teeth, a vertical alignment force is desirable, and mesiodistal and buccolingual forces are undesirable. This led us to conclude that the force system produced by passive ligation is more accurate in terms of delivering a more consistent desired force (Fz in this case) and lower undesired forces (Fx and Fy in this case).

We agree with Brezniak et al that the moments require more in-depth analyses; a challenge in this study was trying to explain every aspect of our data and produce a logical explanation for it, especially moments. The sources of the moments are not limited to those mentioned in their letter; in reality, the bracket-wire interface can produce moments that are extremely complicated and cannot be currently explained by using the center of resistance as a reference point. We hope that further tests can help us to an understanding of the bracket-wire interface.

In our study, there was simply no way to quantify friction and binding, and distinguish between them. Our Fx forces constituted resistance to sliding, which includes friction and binding. We are in the final stage of building a device dedicated to studying resistance to sliding in detail and in 3 dimensions, and we look forward to studying this phenomenon in more detail. The concept of binding is poorly understood, and this has produced many misconceptions in orthodontics; that is why we need to study this phenomenon.

Near the end of their letter, Brezniak et al quoted a sentence from our conclusion section and suggested that the conclusion is inappropriate. However, immediately preceding the quoted sentence, we wrote "Based on those findings, we might not be able to make definite predictions on the effect of these differences on the actual tooth movements. However, it is safe to conclude that different force systems produce different types of tooth movement; therefore, we would expect to see more vertical canine movement and less tipping of the adjacent teeth with passive ligation compared with conventional ligation."

Finally, we stated in our conclusion that the force system produced in this in-vitro study by passive self-ligation was more accurate because more consistent vertical extrusion forces (the desired force) and less mesiodistal or buccolingual forces (undesired forces) were generated. We assumed that *AJO-DO* readers would recognize that this is the first of many tests with the orthodontic simulator, and our data provided an example of its capabilities. It has taken 6 years to prepare and validate a 3-dimensional orthodontic force measurement tool that will be used for many tests to better understand a vaguely understood area of orthodontics. We continue to investigate the effects of the ligation method, and we are now gathering data, using a much larger sample size to be able to perform statistical tests. These data will be collected by starting the canine in the displaced position and ligating the teeth from the anterior to the posterior sequentially.

We have been approached by many academics and clinicians with numerous interesting research proposals to use this device, which is giving us a unique view into the world of 3-dimensional orthodontic mechanics. We plan to start an internship program for those interested in using the University of Alberta orthodontic research laboratory to investigate specific orthodontic biomechanic applications as part of a degree program or simply out of curiosity. We thank the doctors for their input and look forward to more discussions as more evidence is published and made available to *AJO-DO* readers.

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Reproducibility of the CVM method: A reply

We read with obvious interest an article published online in October 2009 about the reproducibility of the cervical vertebral maturation (CVM) method (Gabriel DB, Southard KA, Qian F, Marshall SD, Franciscus RG, Southard TE. Cervical vertebrae maturation method: poor reproducibility. Am J Orthod Dentofacial Orthop 2009;136:478.e1-7). We would like to express a few concerns with regard to the methodology and the interpretation of the results of this study on the reproducibility of the CVM method.

First, in "Material and methods," the authors reported that the training of the orthodontists judging the CVM method consisted of their receiving a hard-copy handout of a schematic representation of the 6 stages of the CVM method and a legend, with no further explanation or training. Therefore, the exposure of the judging orthodontists to the method consisted of an extremely limited self-learning experience.

Also, the schematic representation of the CVM method that was given to the orthodontists (Fig 1 in Baccetti et al[1]) never was proposed by the original authors as a guideline for the implementation of the CVM method in a clinical setting. That article described at least 2 examples of the shape of the third and fourth cervical vertebrae for the same CVM stage (more specifically, for stages CS 3, CS 5, and CS 6).

We actually are thankful to the authors for offering us an indirect suggestion to give clinicians and readers more detailed practical tips to perform the CVM method routinely on lateral cephalograms. Any descriptive categorization or staging of a biologic system requires an understanding of the nuances and subtleties of the method, since there is a gradual transition from 1 stage to the next.

Even considering the limited training opportunity of the judging orthodontists in the study, another concern relates to the interpretation of the results. As reported in the title (for us, it is highly unusual to include the study's conclusions in the title), the reproducibility of the CVM method was defined as "poor." In the introduction, the authors recommended the use of a "stringent measure of association . . . for measuring agreement between judges." However, no reference scale for the interpretation of the weighted kappa values for agreement between observers was reported in "Material and methods."

If we look at the results in Table IV, the weighted kappa coefficient for intraobserver agreement for individual cephalograms was between 0.36 and 0.79, with 9 of 10 observers scoring more than 0.41. According to the most widely used scale for the interpretation of weighted kappa in studies on intraobserver agreement (Landis and Koch[2]), a kappa value greater than 0.41 indicates either moderate (0.41-0.60) or substantial (0.61-0.80) agreement. It is noteworthy that 50% of the observers showed substantial agreement, 40% had moderate agreement, and only 1 observer showed fair agreement. The longitudinal portion of the study reported even better scores. We wonder how the authors were induced to define as "poor" an agreement that typically is considered to be moderate to substantial.

Interestingly, Ballrick et al[3] from Ohio State University performed a similar study on both the accuracy and the reproducibility of the CVM method in orthodontic graduate students. Their results showed very good reproducibility (kappa value, 0.82), which would be interpreted as "almost perfect agreement" according to the scale by Landis and