Modification of the bidimensional system

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In the mid 1970s, Schudy and Schudy developed and described an edgewise bimetric system in which there were brackets with 0.016-inch slots on the incisors and canines and brackets with 0.022-inch slots on the premolars and molars. Modeling after Schudy and Schudy, Gianelly devised a similar, preadjusted system called the bidimensional system, in which the incisor brackets have 0.018-inch slots while the remaining teeth have brackets with 0.022-inch slots. We have further modified the bidimensional system and developed a dual-slot system. Hence, this article compares the bidimensional and dual-slot systems and provides justification for both. The main concerns regarding the bidimensional and dual-slot systems are posterior “play” and lack of three-dimensional control. We rationalize both as well as the self-ligating hybrid and dual-slot system. Orthodontics 2011;12:10–21.

Key words: bidimensional, bimetric, self-ligating, dual slot

Even though straight-wire, or preadjusted, edgewise appliances have achieved universal acceptance, there has been little discussion of their clinical advantages in regard to treatment time, chair time, comfort, hygiene, or treatment results. As Harradine noted: “No study ever demonstrated that preadjusted edgewise appliances were superior to plain edgewise, but the former are overwhelming preferred for reasons that are regarded by clinicians as being self-evident and in no need of the highest order of scientific proof.”¹ In a retrospective study comparing the treatment results of Roth (straight-wire) and standard edgewise appliances using two occlusal indices, there were no significant differences found between the two appliances.² In fact, despite using the Roth appliance, experienced orthodontists still found it difficult to obtain all six keys to normal occlusion.
To this juncture, the purpose of this article is not to demonstrate superior-
ity of a modified bidimensional system over other edgewise appliances, but
rather to justify our adaptations of Gianelly’s bidimensional system from a ra-
tionale viewpoint with the best available evidence.

BIMETRIC SYSTEM

In the mid 1970s, Schudy and Schudy\(^3\) described and rationalized a fixed orth-
odontic appliance system that incorporated two bracket slot sizes, which they
called the bimetric system. It was a standard edgewise appliance system (zero
base) in which the incisors and canines had brackets with 0.016-inch slots and
the premolars and molars had brackets with 0.022-inch slots (Fig 1). They also
argued for what they called the precision-fit principle, meaning that in the fin-
ishing stages, the wires should fully engage the bracket slots, thus eliminating
or significantly reducing “play.” To fully engage and fill the dual-slot brackets,
a 0.016 \(\times\) 0.022-inch stainless steel wire is twisted and torqued 90 degrees
distal to the canines. As a result, a ribbon archwire, 0.022 \(\times\) 0.016-inch, is cre-
ated in the posterior segments.

BIDIMENSIONAL SYSTEM

Modeling after Schudy and Schudy, Gianelly\(^4\) developed a preadjusted, edge-
wise bidimensional system that had brackets with 0.018-inch slots on the inci-
sors and 0.022-inch slots on the canines, premolars, and molars (Fig 2). Gianelly
placed 0.022-inch slots on the canines, whereas Schudy and Schudy
had 0.016-inch slots on the canines. Gianelly made cogent arguments for
smaller bracket slots on the incisors (0.018 \(\times\) 0.025-inch) for three-dimensional
control and a tight fit as well as for larger bracket slots (0.022 \(\times\) 0.028-inch) on
Modification of the bidimensional system

Gianelly gave the following justifications for his bidimensional system: “The reason I did this was to combine precision with practicality. For example, one movement that requires torque control is the retraction of the maxillary incisors. In the edgewise technique, full engagement of the wire in the incisor brackets is generally necessary to control the axial inclination of the incisors during retraction. I use a 0.018 × 0.025-inch vertically slotted, programmed bracket on the central and lateral incisors and a 0.022 × 0.028-inch vertically slotted bracket posteriorly. For retraction, I simply insert a 0.018 × 0.022-inch wire for full engagement of the incisor brackets and retract the incisors bodily by means of sliding mechanics, because the wire is ‘undersized’ in the buccal segments. According to a New York University study, only 7% of wires ‘fill the slots.’ My percentage during incisor retraction approaches 100%. The undersized posterior part of the wire also relieves me of the technical burden of adjusting the torque to the posterior brackets. My chair time is reduced, and I don’t have to contend with loops that may impinge on the tissues.”

Gianelly pointed out that few orthodontists fill the edgewise slots, especially for 0.022-inch slot users, so this is support for at least full 3D control of the incisors with 0.018 × 0.022-inch or 0.018 × 0.025-inch stainless steel archwires. For space closure, by sliding, Gianelly’s working wires are 0.016 × 0.022-inch.
stainless steel or $0.018 \times 0.022$-inch stainless steel with crimp-on hooks distal to the lateral incisor brackets and closed nickel-titanium (Ni-Ti) coils attached to the crimp-on and molar hooks. He made an important point that for space closure, $0.017 \times 0.025$-inch or $0.018 \times 0.025$-inch stainless steel wires are not viable substitutes for the $0.016 \times 0.022$-inch or $0.018 \times 0.022$-inch stainless steel wires because the horizontal dimension of 0.025 inches creates too much resistance to sliding for space closure. Resistance to sliding is simply a combination of classical friction and a coefficient of binding. In fact, Gianelly typically advocated using rectangular wires throughout treatment.

Nonetheless, a criticism of the bidimensional system is a lack of 3D control with full-sized $0.018 \times 0.025$-inch wires in the incisors but undersized in the posterior teeth due to the $0.022$-inch slot. Gianelly’s counter was the same as Schudy and Schudy: To fill the posterior bracket slots, twist a $0.018 \times 0.022$-inch stainless steel wire 90 degrees distal to the lateral incisors and create a ribbon arch with $0.022 \times 0.018$-inch stainless steel wire in the posterior. However, twisting or torquing a wire 90 degrees is cumbersome and unconventional for most orthodontists. Another option is to bend custom torque into rectangular archwires, as is traditionally done. Be that as it may, these solutions for lack of 3D control have never impressed orthodontists enough to adequately justify the bidimensional system. This in part may account for why only 4.7% of responding orthodontists reported routinely using the bidimensional system. This in part may account for why only 4.7% of responding orthodontists reported routinely using the bidimensional system.6
Having worked with Gianelly’s bidimensional system for over 20 years, we have developed some conceptual and mechanical alterations, which, for communication purposes, we will call the dual-slot system. It must be noted, however, that Gianelly deserves the credit for providing the foundation and framework for our modification of the bidimensional system.

Proffit et al.7 argued the advantages and disadvantages of the 0.018-inch slot vs the 0.022-inch slot from the perspective of sliding mechanics and torque control (Table 1). For instance, Proffit et al.7 stated that sliding teeth along an archwire necessitates at least 2 mil (0.002-inch) of clearance—4 mil (0.004-inch) of clearance is desirable. So, with this principle, the advantage of a 0.022-inch slot would be that larger 18 mil (0.018-inch) wires could be used (compared to 16 mil [0.016-inch] wires in an 0.018-inch slot). Therefore, larger, stiffer wires would have fewer tendencies for notching and deformation. So, specifically for space closure by sliding, it would be advantageous to have brackets with 0.022-inch slots posterior to the extraction spaces for a looser fit, reduced resistance to sliding, and the use of stiffer wires.

However, for torque control in the incisors, it is better to have brackets with 0.018-inch slots because full-sized wires can be engaged if full 3D control is necessary. A 0.022-inch slot would not be advantageous for torque control since full-sized 0.022 × 0.028-inch wires are too stiff to be engaged into the bracket slots. Therefore, using Proffit et al.’s7 rationalization, a bidimensional system would integrate the best of both the 0.018-inch and 0.022-inch slot systems: a tight fit in the incisors for full 3D control and a loose fit elsewhere for space closure by sliding. As an aside, various studies have shown that treatment times are shorter8–10 and outcomes may be better with a 0.018-inch slot compared to a 0.022-inch slot.8

### Table 1  Comparison of the various slot sizes from a perspective of space closure (assuming sliding mechanics) and torque control

<table>
<thead>
<tr>
<th>Slot size</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.018-inch slot</td>
<td>Anterior torque control: Full 3D control with 0.018 × 0.025-inch archwires</td>
<td>Space closure: Lighter undersized stainless steel wires more prone to deformation and notching</td>
</tr>
<tr>
<td>0.022-inch slot</td>
<td>Space closure: Larger, stiffer undersized stainless steel wires, less deformation and notching</td>
<td>Torque control: Full-sized 0.022 × 0.028-inch archwires are too stiff to be used so undersized finishing wires must be used</td>
</tr>
<tr>
<td>Bidimensional (dual-slot) 0.018- and 0.022-inch slots</td>
<td>Space closure: Larger, stiffer undersized rectangular wires (0.016 × 0.022- or 0.018 × 0.022-inch), less deformation and notching with 0.022-inch slots in posterior teeth, and effective 3D control of incisors during space closure with 0.018-inch slot in the anterior.</td>
<td>Possible loss of posterior 3D control with full-sized 0.018 × 0.025-inch archwires (counterarguments made in this article)</td>
</tr>
</tbody>
</table>

**MODIFICATION OF THE BIDIMENSIONAL SYSTEM: THE DUAL-SLOT SYSTEM**

Having worked with Gianelly’s bidimensional system for over 20 years, we have developed some conceptual and mechanical alterations, which, for communication purposes, we will call the dual-slot system. It must be noted, however, that Gianelly deserves the credit for providing the foundation and framework for our modification of the bidimensional system.

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However, for torque control in the incisors, it is better to have brackets with 0.018-inch slots because full-sized wires can be engaged if full 3D control is necessary. A 0.022-inch slot would not be advantageous for torque control since full-sized 0.022 × 0.028-inch wires are too stiff to be engaged into the bracket slots. Therefore, using Proffit et al.’s7 rationalization, a bidimensional system would integrate the best of both the 0.018-inch and 0.022-inch slot systems: a tight fit in the incisors for full 3D control and a loose fit elsewhere for space closure by sliding. As an aside, various studies have shown that treatment times are shorter8–10 and outcomes may be better with a 0.018-inch slot compared to a 0.022-inch slot.8
In regard to criticism of play or lack of 3D control in the posterior segments with the bidimensional or dual-slot system, as a conceptual difference, we have never twisted a $0.018 \times 0.022$-inch stainless steel wire distal to the lateral incisors in an attempt to enhance 3D control in the posterior, as advocated by Gianelly and Schudy and Schudy. If most orthodontists using a $0.022$-inch slot finish with $0.019 \times 0.025$-inch wires, a full-sized $0.018 \times 0.025$-inch wire in a bidimensional or dual-slot system is not much different. Customized torque can still be used in the posterior segments if necessary.

Furthermore, it has been shown that there is tremendous morphologic variability in the facial surfaces of teeth. Specifically, Germane et al. reported the greatest variability in the posterior teeth. Even a very slight difference in bracket height placement, as little as 1 mm, could alter tooth inclination as much as 10 degrees. Creekmore and Kunik elaborated on this argument and showed that variations in tooth structure, such as variable facial surfaces, crown-root angulations, and atypical crown shape, warrant variations in tip, torque, rotation, and height parameters to obtain optimal results for each tooth.

In reference to a recent article by Mulligan, which differentiated the moments created with full vs partial appliances, Keim noted that “one of the most common mistakes that arises as a result of standardized treatment protocols is the tendency to place full appliances in every case. Not only is this unnecessary in many patients, but if we analyze the resulting force systems, it may actually be contraindicated.” Furthermore, Mulligan often avoided bracketing the premolars and sometimes canines so that these teeth could be used to gauge whether the arches are expanding or constricting. Some have called this the neutral zone: equilibrium between lips, cheeks, tongue, and muscle forces exerted on teeth, particularly in the buccal segments, and the preexisting buccal segments may be in their most stable functional environment.

In reference to the “equilibrium effects on the dentition,” Profitt et al. stated that although masticatory forces are much stronger, the lighter pressures of the lips, cheeks, and tongue are much greater in duration, and these pressures, even at rest, are sustained most of the time and affect tooth position. To demonstrate this, they described the case of a woman who has tremendous unilateral splaying of the left posterior and anterior teeth subsequent to loss of lip and cheek pressure due to an infection and paralysis, with resulting pronounced tongue pressure. Arguing for a new soft tissue paradigm over the old “Angle ideal dental occlusion” paradigm, Profitt et al. showed evidence for the new model. For instance, in regard to stability of results, the old model was related primarily to dental occlusion, whereas the new model relates stability primarily to soft tissue pressure and equilibrium effects. Therefore, soft tissue balance and equilibrium even after teeth are moved orthodontically will influence tooth position. So, even if you have a prescription in your appliance that results in a certain 3D position of the teeth, the patient’s oral environment may provide the ultimate stable position of the dentition.

For these reasons and others, in the finishing stage of treatment, some orthodontists use lighter wires, anterior segmental archwires and no posterior archwires with or without vertical elastics, circumferential retainers, and canine-to-canine vacuum-formed retainers to permit posterior settling. Again, the 3D control of the posterior segments that the orthodontist strives to obtain may be altered with settling and equilibrium of soft tissue on the teeth. Interestingly, Lyotard et al. demonstrated the results of removing final archwires at the end of active orthodontic treatment for 4 weeks. Mandibular crowding, overjet, and interproximal contacts worsened; however, marginal ridges, occlusal contacts, and total American Board of Orthodontics scores improved. Assuming that anterior segmental archwires are left intact, the authors concluded that...
their study supports the practice of removing the archwires from the posterior teeth a few weeks prior to debonding for settling and improved occlusion.

If orthodontists using 0.022-inch slot appliances finish with 0.019 × 0.025-inch stainless steel wires, it may be argued that these orthodontists have play throughout their system, whereas the dual-slot system has play only in the posterior and complete control of anterior teeth with full-sized 0.018 × 0.025-inch finishing wires. With play in the posterior and complete control in the anterior, teeth may level and align faster and space closure may be enhanced because of reduced resistance to sliding in the posterior segments.

If inclination/torque is dynamic and changes in the posterior, particularly the molars, over time as Marshall et al demonstrated, one might consider two possibilities: custom torque for each patient or to simply use the same for each patient. With normal, transverse growth of the maxillary and mandibular first molars from age 7.5 to 26.4 years, the maxillary molars upright lingually 3.3 degrees. Maxillary intermolar width increases 2.8 mm, and the mandibular molars upright 5.0 degrees and mandibular intermolar width increases by 2.2 mm. Therefore, an attempt to prescribe a static facial torque in the buccal segments may ultimately be altered by growth or settling of the occlusion over time. So one may facetiously ask whether varying posterior 3D prescriptions for patients depending on their age is necessary.

Another critical question is whether specific, ideal torque values are any healthier than others. Is there morbidity generally associated with malocclusion? Ackerman and Proffit stated, “Although the concept of ideal occlusion has taken precedence as the ultimate goal in clinical orthodontics for some 110 years and serves well as an adopted arbitrary convention and a clinical gold standard, it has no verifiable scientific validity. No one has yet demonstrated that ideal occlusion provides significant benefits in oral or general health or that it significantly improves oral function.” Research seems to support Ackerman and Proffit’s position. For instance, malocclusion is generally not associated with temporomandibular disorders (TMD), and orthodontics cannot lessen or prevent the future development of TMD. Contrary to what may seem reasonable, a recent systematic review identified an absence of reliable evidence describing the positive effects of orthodontic treatment on periodontal health. In fact, orthodontic therapy results in small detrimental effects to the periodontium: alveolar bone loss, gingival recession, and increased periodontal pocket depth.

Another point is related to the issue of expansion. Interestingly, many advocates of arch development and upright mandibular posterior teeth have inclination (lingual crown torque) prescriptions of –25 or –30 degrees, not –12 or –15, for the mandibular first molars. It is possible that expanded archwires may override the built-in prescription of –25 or –30 degrees and produce upright molars. Another difference in biomechanics between our system and Gianelly’s is that for space closure, Gianelly generally advocated separately retracting canines and then the four incisors. On the contrary, our system employs en masse retraction for the six anterior teeth, except for cases of anterior arch-length discrepancies or crowded anterior teeth, such as lingually blocked lateral incisors. Then, we separately retract the canines only to relieve crowding. This treatment philosophy is also held by Burstone, who said: “Since relatively low forces are capable of retracting six teeth, there is little logic to separate retraction of canines followed by retraction of the four incisors. For that reason, only patients who have anterior arch-length problems with anterior crowding require separate canine retraction.” This would prevent round-tripping teeth.

This is supported by Heo et al, who found no significant difference in posterior anchorage loss between en masse retraction of the six anterior teeth and separate, two-step retraction of the canines followed by the four incisors;
two-step retraction took longer. Likewise, Xu et al,\textsuperscript{33} in a randomized clinical trial comparing en masse and two-step retraction in 64 growing boys and girls with Angle Class I and II malocclusions requiring maxillary premolar extractions and maximum anchorage using an MBT prescription and 0.022 × 0.028-inch bracket slots, headgear, and some transpalatal appliances, found that contrary to what some clinicians believe, two-step retraction is not more effective than en masse retraction in preventing clinically meaningful anchorage loss. And, again, two-step retraction lengthens treatment time.

As an example, if you want to close maxillary first premolar extraction spaces by 8 mm, assume that you can close the space 1 mm per month for a total of 8 months to retract the canines and then another 8 months to retract the incisors. However, if you retract the six anterior teeth en masse, you can close the space in 8 months, saving 8 months of treatment. Moreover, a recent study concluded that there should be no expected difference in external apical root resorption between two-step and en masse space closure procedures.\textsuperscript{34}

As mentioned previously, Gianelly routinely used rectangular wires throughout treatment, whereas our initial wires are generally round Ni-Ti wires, as advocated by Proffit. For instance, Proffit et al\textsuperscript{7} state that, “A tightly fitting resilient rectangular archwire for initial alignment is almost always undesirable because not only is frictional resistance to sliding likely to be problematic, the wire produces back-and-forth movement of the root apices as the teeth move into alignment.”

With moderate to severely rotated teeth, resilient round wires would offer another advantage because they have flexibility in both the horizontal and vertical dimensions, whereas resilient rectangular wires have more flexion in the vertical dimension and limited flexion in the horizontal dimension. Table 2 is an overall comparison of differences between the Gianelly bidimensional technique and the dual-slot system.

### Table 2: Comparison of the differences between Gianelly’s bidimensional technique and the dual-slot system

<table>
<thead>
<tr>
<th>Comparisons</th>
<th>Bidimensional technique</th>
<th>Dual-slot system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canine vs en masse retractions</td>
<td>Canine retraction</td>
<td>En masse retraction except for anterior arch-length discrepancies</td>
</tr>
<tr>
<td>Initial wires</td>
<td>Generally rectangular</td>
<td>Generally round</td>
</tr>
<tr>
<td>Vertical slots</td>
<td>Yes, for auxiliaries, and uprighting springs in canines for anterior labial forces in the mandibular arch in Class II extraction cases to prevent an overjet with intra-arch mechanics</td>
<td>No</td>
</tr>
<tr>
<td>Ball hooks</td>
<td>No</td>
<td>Yes, on most teeth</td>
</tr>
<tr>
<td>Bracket torque</td>
<td>No posterior torque</td>
<td>More torque on anteriors and posterior torque</td>
</tr>
</tbody>
</table>
| Rationalization for lack of 3D control in posterior teeth | Twist a 0.018 × 0.022-inch stainless steel wire 90 degrees distal to the lateral incisors to create a ribbon arch | Can place conventional torque in archwires
|                                      |                                                              | More variability of facial surfaces in the posterior teeth
|                                      |                                                              | Mulligan Mechanics—generally premolars and sometimes canines are not bracketed, especially with use of V-bends
|                                      |                                                              | Neutral zone
|                                      |                                                              | With growth, molars tend to upright                                             |
| Self-ligation model                  | No                                                           | Propose dual-slot self-ligating and hybrid self-ligating models                 |

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Modification of the bidimensional system

Rinchuse and Miles\textsuperscript{35} described a hybrid self-ligating bracket systems in either entirely 0.018-inch slots or entirely 0.022-inch slots in which the anterior brackets are active with a spring clip and the posterior brackets have a passive slide, very similar to a bimetric, bidimensional, or dual-slot system. Since the gingival horizontal wall is compromised by an obliquely inclined spring clip, the active self-ligating brackets are smaller than their conventional counterparts and not truly $0.018 \times 0.025$- or $0.022 \times 0.028$-inch. Therefore, this hybrid system would have so-called reduced bracket slots in the anterior for a tighter fit and enhanced 3D control, especially with undersized $0.019 \times 0.025$-inch stainless steel finishing wires in 0.022-inch slots, and a looser fit with possibly reduced resistance to sliding with passive brackets\textsuperscript{36–38} in the posterior for leveling, alignment, and space closure.

In an in vitro study, Badawi et al\textsuperscript{39} found that active self-ligating brackets are more effective in torque expression than passive self-ligating brackets in 0.022-inch slots and $0.019 \times 0.025$-inch stainless steel wire. Likewise, if many orthodontists use a 0.022-inch slot and only finish with $0.019 \times 0.025$-inch stainless steel wire,\textsuperscript{11} it might be desirable to use an active self-ligating system since there may be more enhanced 3D control and dental esthetics of the incisors. However, if a clinician is filling the 0.018-inch bracket slots with $0.018 \times 0.025$- or $0.0175 \times 0.025$-inch finishing wires, a passive self-ligating system might be advantageous, possibly reducing resistance to sliding in the initial stages of treatment. However, this is controversial, with notching and binding as variables affecting resistance to sliding.\textsuperscript{40}

To obtain excellent 3D control in the anterior teeth and at the same time have even more reduced resistance to sliding in the posterior, a dual-slot self-ligating system can be used with active 0.018-inch slot anterior brackets and passive 0.022-inch slot posterior brackets. Other self-ligating permutations are all-active or all-passive dual-slot systems. Table 3 codifies the possible hybrid

\begin{table}
\centering
\begin{tabular}{|l|c|c|c|}
\hline
Bracket system & Slot size (inches) & Active & Passive \\
\hline
Hybrid self-ligating 0.018-inch & 0.018 & Anterior & Posterior \\
Hybrid self-ligating 0.022-inch & 0.022 & Anterior & Posterior \\
Dual-slot self-ligating & 0.018 & 0.022 & Anterior \\
Dual-slot self-ligating active & 0.018 & 0.022 & Anterior \\
Dual-slot self-ligating passive & 0.018 & 0.022 & Anterior \\
\hline
\end{tabular}
\caption{Summary of the possible hybrid or dual-slot self-ligating systems adapted after Rinchuse and Miles\textsuperscript{35}}
\end{table}

“With moderate to severely rotated teeth, resilient round wires would offer another advantage because they have flexibility in both the horizontal and vertical dimensions, whereas resilient rectangular wires have more flexion in the vertical dimension and limited flexion in the horizontal dimension.”

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and dual-slot self-ligating systems. Figure 4 shows the permutations of manipulating slot size, active or passive self-ligating brackets, and a hybrid system (same slot size but active anterior and passive posterior brackets).

Paik et al. applied the principles that Rinchuse and Miles developed to describe a hybrid bracket-tube system called the hybrid sliding mechanics of low friction, which is a combination of passive self-ligating brackets on the premolars, conventional tubes on the molars, and conventional twin brackets on the anterior teeth. However, much of the rationale for this system is based on in vitro data regarding friction and passive self-ligating brackets.

CONCLUSION

We have presented a cursory review of the bimetric and bidimensional systems juxtaposed with a dual-slot system that offers an alternative to Gianelly’s system. Furthermore, we codified Rinchuse and Miles’ thoughts on hybrid and dual-slot self-ligating systems.

ACKNOWLEDGMENTS

Since we were orthodontic residents at the University of Pittsburgh in 1974, we have been impressed with Dr Anthony Gianelly’s (1936–2009) research, articles, and particularly his bidimensional system. He was a very unassuming and humble man. We have used a bidimensional prescription that we have modified for over two decades, which this paper addresses. However, without Tony’s concepts and principles, this paper would not have been possible.
REFERENCES