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Authors' response

Thank you to Henry Nahoum for carefully reading and commenting on our article regarding the force systems of removable thermoplastic appliances.

In fact, there are several different parameters that can influence the biomechanics of the aligners, including (but not limited to) the material properties of the aligner, its thickness, and the fitting accuracy. We are aware that these parameters do influence the clinical outcome, but the evaluation of these parameters was out of the scope of our study. However, such investigations might be the focus of future studies.

According to the correspondent, using an in-vitro setup for simulating tooth movements might limit the applicability of the presented approach. Furthermore, he stated that using a "center of resistance" for describing a tooth movement (as it is done in our setup) does not reflect the correct mechanical behavior of the tooth in the alveolus. We are aware that we could not consider the clinical parameters in our study, and we hope that these limitations are clearly expressed in the discussion of the article. However, the use of the center of resistance is an accepted idealization used to describe the tooth movement, and after using the presented approach of experimental simulation of the orthodontic tooth movement in several previous studies, we feel confident that the results of these simulations provide a rather good approximation of the clinical outcome. This holds especially for this study, since we were able to analyze the clinical outcome of these cases in another part of this study,[1] which was in good correlation with the results of the simulations.

Furthermore, Dr Nahoum pointed out that we did not pay attention to the fact that force systems of aligners are constantly changing while being worn. Although this is not stated directly in our article, we repeatedly inserted each aligner and performed the simulation at least 3 times in a row for each aligner to allow the teeth to "slip in the aligner." Unfortunately, this part of the text was accidentally removed in an attempt to improve the readability of that section. Altogether, the tooth movement was implemented in increments. After every increment movement (transformed by the stepping motors of the positioning tables), the force systems currently generated by the aligners were remeasured, and the updated forces were used for the simulation.

Finally, Dr Nahoum emphasized that we did not mention Nahoum's contour appliance. We included the Kesling article because it is one of the oldest articles that reported the use of elastic positioners in orthodontics (here still primary for minor tooth movements after debonding), and many other publications refer to this article as the basic idea that finally led to aligner systems. Due to the limited space available in the article, it was not possible to mention every available article on this topic.

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Analysis of data in removable thermoplastic aligner study

I read with great interest the article in the June issue, "Forces and moments generated by removable thermoplastic aligners: Incisor torque, premolar derotation, and molar distalization" (Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Am J Orthod Dentofacial Orthop 2014;145:728-36), investigating the forces and moments generated by Invisalign aligners, since this is an area that needs much more research as the technique grows. I applaud the researchers for their excellent work but have a few questions and concerns about the study.

The researchers stated that "the tooth movement to be investigated was performed in isolation at the beginning of the treatment to make it clearly distinguishable from any other tooth movement." Then in Figure 4, they showed graphs of the forces and simulated tooth movement of the maxillary incisor undergoing what is presumed to be buccal crown torque. The authors highlighted the positive forces in the z-direction (buccal) and the moment about the y-axis (buccal crown torque). However, where did all the other forces and moments come from? According to the graph, there's a large negative force in the y-direction (distal) on the tooth and moments in all directions. Furthermore, the displacement graph (*B*) shows movement of the tooth in the distal (y) direction. These other data are seemingly not addressed until the end of the discussion when the authors stated "we used patients and not a complete experimental setup. Therefore, only the main force systems corresponding to the tooth movement…can be directly compared…"

This may explain why those data were not compared between groups, but not why the data were seemingly completely ignored. The maxillary incisor was isolated, and buccal crown torque was placed with aligners, but all sorts of forces and moments were measured, and the tooth moved 2.5 mm distally! This seems like a pretty significant finding to me, and similar side effects of aligners have been found in previous studies.[1]

There is also an issue with the way bodily movement was measured in this study. In Table II, distalization was measured only with a force in the x-direction (distal), and then the movement was presumably measured by displacement of the molar crown in that direction. But to distalize a tooth bodily, there must be distal root torque as well, or else all the clinician has done is tipped the crown of the molar. Therefore, the moment about the y-axis should have been investigated further. Figure 7, *B* shows an average negative moment about the y-axis, presumably showing this distal root torque that produced bodily tooth movement on the distalized molar. But Figure 5, *B* shows an average positive moment about the y-axis for palatal root torque (or buccal crown torque) on the maxillary incisor. How can 2 moments in opposite directions produce root movement in the same direction? This anomaly needs more research. In the discussion, the researchers stated that "our results suggest that bodily tooth movements…can also be performed using Invisalign aligners…" I do not agree that the data in this study showed this conclusively and feel that this is an irresponsible statement.

The researchers acquired excellent data in this study, clearly demonstrating exponential force and moment decay of the aligners, and useful comparisons of certain forces with and without attachments. However, it seems that the data were "cherry-picked" to make certain statements. I believe that the data in this study could be very useful but should perhaps be analyzed from a different perspective.

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Authors' response

First, we want to thank Dr Daniel A. Kuncio for his interest in our article.

Regarding all the other forces and moments, Dr Kuncio wondered where they did come from. We have to state that it is a really interesting question, dealing with 1 key characteristic of an aligner. An aligner has a complex 3-dimensional geometry that is loaded by placing the aligner onto the dental arch. We planned the aligner therapy so that isolated tooth movements should have been accomplished: ie, only the tooth in question should have deformed the aligner material around itself, delivering exactly the force system necessary for the desired tooth movement. Due to the complex aligner geometry, it is of course impossible to predict the exact aligner deformation for such an isolated tooth movement. Thus, the aligner steps usually are designed so that the tooth's crown shall be moved in small, incremental steps, ignoring biomechanically exact force systems. The complex deformation of the aligner will always generate additional force and moment components. Moreover, displacement of the tooth with respect to its center of resistance must be taken into account.

Considering the molar distalization, Table II only lists the forces; however, moments are displayed in Figure 7 as well. We hope this will help to understand our findings, especially as the clinical results[1] showed bodily molar movements with our aligners.

About the accusation of "cherry-picked" data to make certain statements: even if you do not agree with all the conclusions we have drawn from our findings, we would