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Integrating Micro-CT and FEA to Explore the Effect of Gap Variability in Orthodontic Aligner Biomechanics

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ABSTRACT

Clear aligners are widely used in modern orthodontic treatment, and multiple finite element analysis (FEA) models have been developed to understand their mechanical response to tooth displacements. Previous studies suggest that the gap size distributions between aligners and teeth play a significant role in determining FEA model outputs, such as reaction forces and contact mechanics. However, the distribution of gaps and the correlation with mechanical response of aligners has not been established. Most studies either assume perfect contact between the aligner and teeth, or apply a constant gap size in their FEA models, which may not accurately represent real-world conditions. Moreover, limited information is available on how gap sizes evolve after multiple removal and application cycles. The present study aims to replicate the gap distribution between aligners and teeth within a FEA model, and to investigate the changes in gap distribution after multiple cycles.

The gap size distribution of an aligner-arch model assembly was obtained from X-ray micro-computed tomography (micro-CT) scans collected at a 17.48-micron resolution, and the information was integrated into a FEA model that was analyzed in Ansys Mechanical (Ansys, Canonsburg, PA, USA). Reaction forces and the equivalent strain distribution were recorded as the central incisor was displaced towards the cheek for 0.20 mm. In order to investigate the impact of repeated removal-application cycles on the evolution of gap distribution between aligners and teeth, the aligners were subjected to multiple fitting cycles and the resulting gap distribution was measured through use of sequential micro-CT scans.

The initial analysis through micro-CT scans indicates that the distribution of gap sizes between aligners and teeth has an average value of 0.181 mm, and yields a corresponding reaction force of 1.32 N at the displaced central incisor. Although the force results generally agree with the previous studies with a constant gap size model and in-vitro experimental data, the equivalent strain distribution shows a high sensitivity with respect to the variant contact points. This finding supports the importance of integrating realistic gap distributions in similar models, particularly when studying material-level response.

Micro-CT scans performed after repeated removal and application cycles suggest that gap sizes change with each cycle. These findings aim to mimic the conditions of patients' daily aligner wear and provide insights into the gradual alterations in fit over time. Understanding these changes is crucial for studying their cumulative effects on aligner performance and treatment outcomes.