Abstract

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Comparison of the in vitro force generation of aligner systems

Objective: The development of directly 3D-printed aligners made from shape-memory polymers has led to recommendations for larger step sizes in staging; however, evidence on the force development of these aligners in relation to the thickness of the material and the magnitude of tooth movement remains limited. The aim of this in vitro study was to determine the forces and torques generated on moved teeth as a function of step size and material thickness.

Materials and methods: A modular 3D-printable orthodontic measurement apparatus (M3DOMA) based on ATI sensors was used. The dental arch was captured with an intraoral scanner (Aoral Scan 3 Wireless, Shining 3D Dental Inc., Hangzhou, China) and imported into OnyxCeph³™ (Image Instruments GmbH, Chemnitz). After base creation and segmentation, movements of a first molar were simulated in steps of 0.1 mm/1°. From this, both 3D models for 3D printing and STL files for direct aligner printing with material thicknesses ranging from 0.4 to 1.0 mm were exported. The aligners were printed with Tera resin (Graphy, Seoul, Korea) using an Asiga Max (Scheu-Dental GmbH, Iserlohn). Thermoformed aligners (CA-Pro) were produced as a control group. Post-processing was carried out strictly according to the manufacturer's instructions. Forces and torques were measured using the measuring apparatus in a shielded enclosure at a constant temperature of 37°C.

Results: The aligners were successfully 3D printed. However, in this configuration, reproducible printing was possible only from a material thickness of 0.5 mm. Aligners with a material thickness greater than 0.8 mm were usable only to a limited extent on the measuring apparatus. The measurements yielded forces ranging from 0.3 to 0.8 N. Force increased with material thickness; however the effect was inconsistent. A relationship between displacement and force and torque generation was apparent but not strictly linear.

Discussion/conclusion: 3D-printed aligners generate relatively low forces that are largely within the ideal range of biological effectiveness. However, within the production workflow and materials tested here, force and torque development was not consistent.