

Biomechanical Investigation of Orthodontic Tooth Movements Induced by Clear Aligners

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INTRODUCTION

Orthodontics is a dentistry specialty which deals with the diagnosis, prevention, management and correction of mal-positioned teeth or jaws including misaligned bite patterns, also called malocclusions. Figure 1 shows the prevalence of malocclusions reported in 2019.

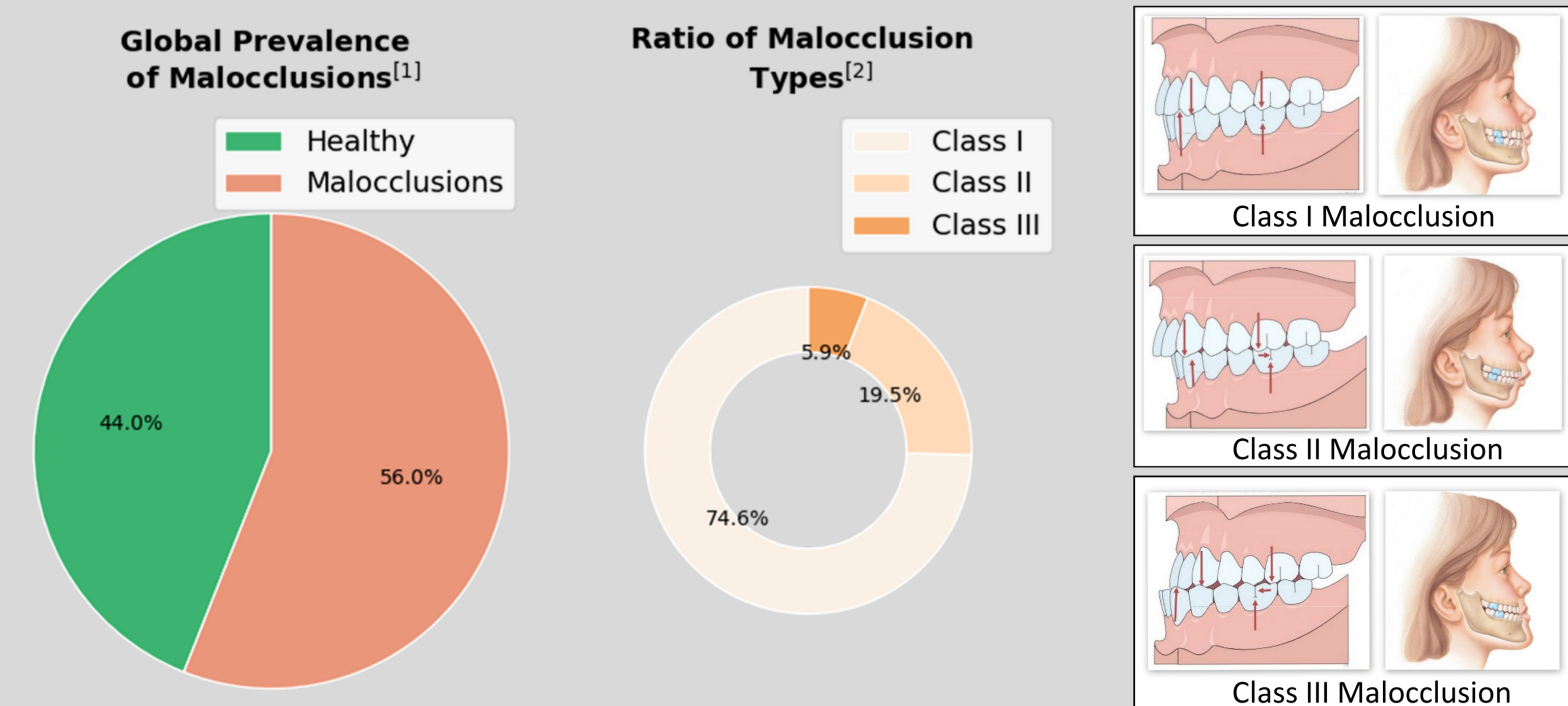


Fig. 1: Global Prevalence of Malocclusions^[3]

The objective of this work was to identify challenging tooth movements from literature as well as from internal revision cases. The identified movements were simulated on an orthodontic force simulator (OFS) to assess the experienced force and torque of each tooth during the movement. A quantitative method should be developed to analyze the internal clinical cases regarding their treatment outcome.

CONCEPT

The individual treatment plans of 20 internal clinical cases were investigated. Three cases were additionally analyzed by superimposing the planned and achieved tooth positions to assess the treatment outcome quantitatively. The simulation of 3° facial crown tipping and 3° axial rotation was done on the OFS (see figure 2). Each tooth is mounted on a sensor measuring all 6 degrees of freedom where one sensor is mounted on a hexapod to enable movements during the experiment.

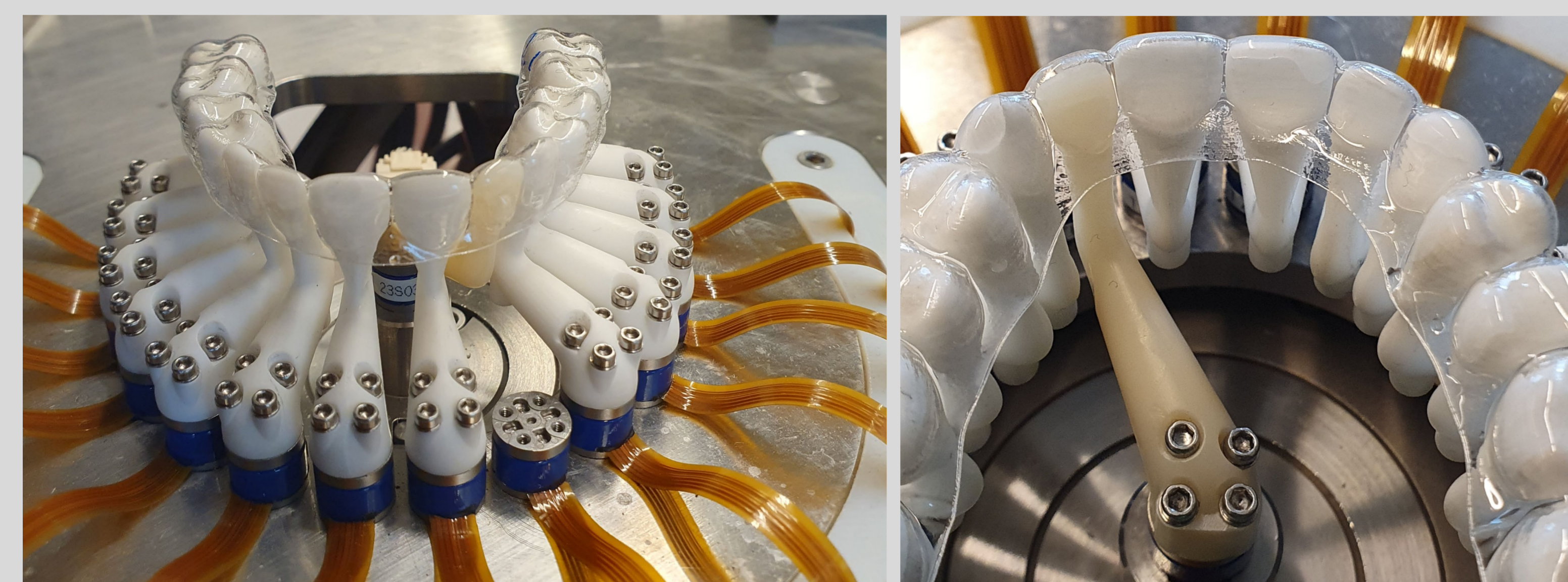


Fig. 2: Setup on the Orthodontic Force Simulator

Eight different attachment designs for the right maxillary lateral incisor were measured on the OFS to first reproduce the findings during the revision case analysis and second, try to create a superior force and torque situation using a new attachment shape to increase the treatment accuracy. The different attachment designs tested are shown in figure 3.

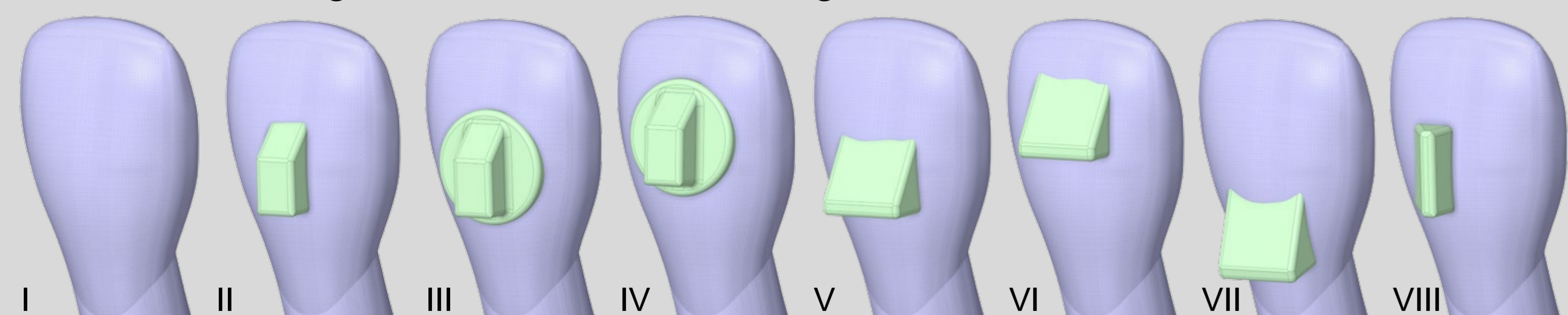


Fig. 3: Attachment Designs tested on the Orthodontic Force Simulator. I: No attachment, II-IV: Reproduction of findings during revision case analysis, V-VIII: Measurement of a new attachment design.

RESULTS

The revision case analysis was not able to detect one single movement, but maxillary lateral incisors were mentioned most frequently as revision cause.

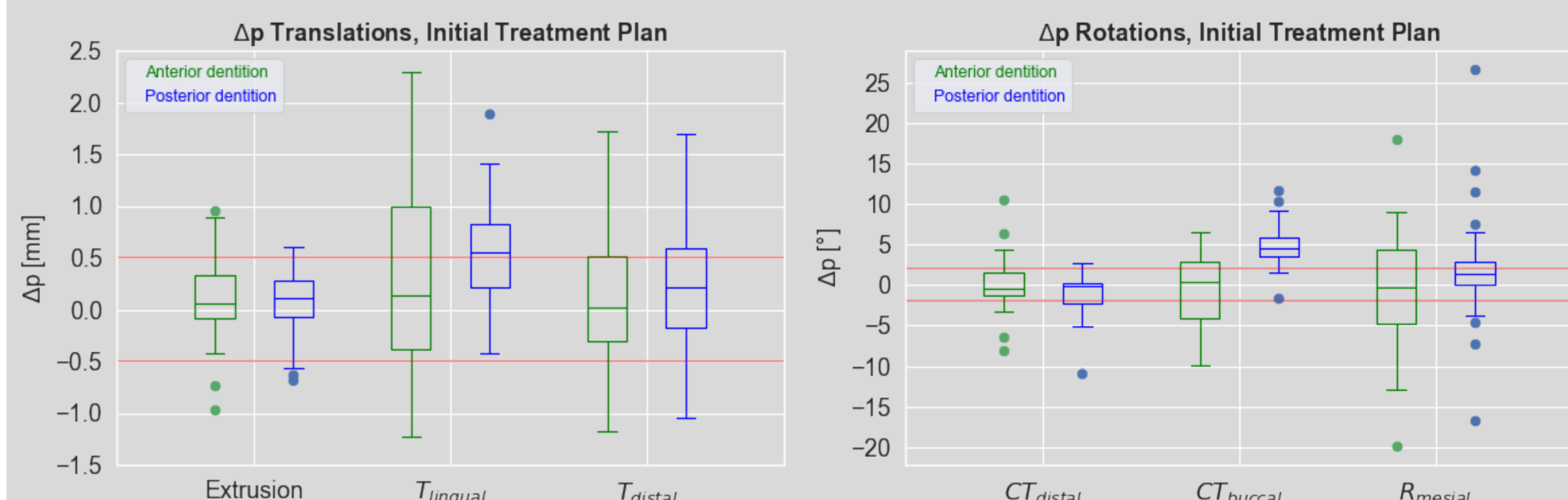


Fig. 4: Deviation Δp between planned and achieved tooth positions. T: Translation, CT: Crown torque, R: axial rotation. Red lines indicate the clinical thresholds for a successful treatment.

- ☞ Intrusion of maxillary lateral incisors and facial crown tip of maxillary central incisor most difficult tooth movements according to literature
- ☞ Treatment predictability higher for anterior dentition compared to posterior dentition^[4]
- ☞ Usage of attachments leads to superior aligner performance for facial crown tip, also confirmed by recent review^[5]. Unclear effect for axial rotations
- ☞ Comparing design II and V, II showed superior performance for facial crown tip mainly due to lower side effects
- ☞ Excessive composite material observed (figure 3) shows minor effect on treatment outcome. Vertical shift induces major effect with intrusive force.
- ☞ Crown collisions frequently lead to low treatment predictability.

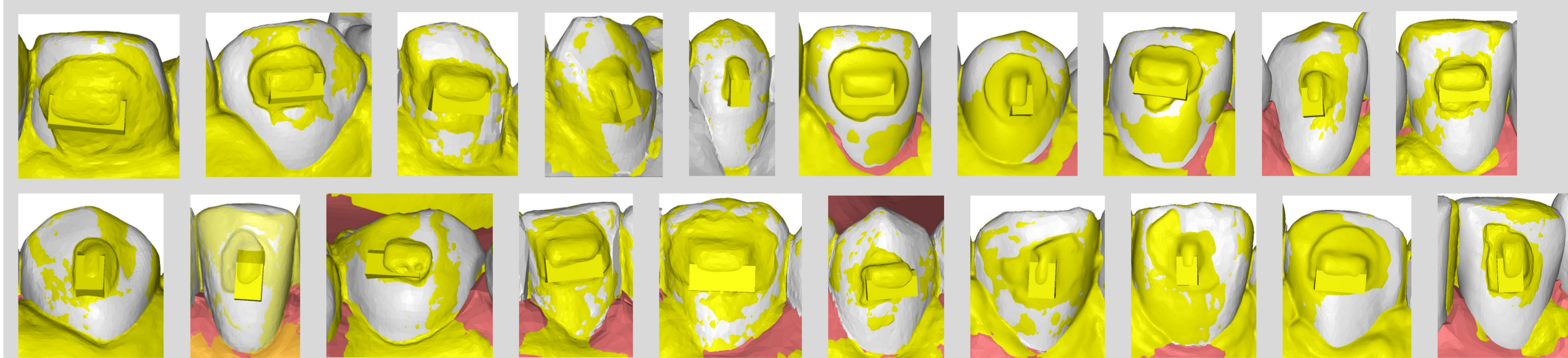


Fig. 3: Local alignment of planned and achieved crowns. Grey crown and sharp rectangular shaped attachments show planned attachment, where the yellow model shows the achieved shape and position.

CONCLUSION

- ☞ Revision case analysis did not show a single movement as problem
- ☞ Effect of movement type on treatment outcome is not the biggest
- ☞ Proper attachment placement can prevent unintended movements

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