Three-Dimensional Assessment of Virtual Clear Aligner Attachment Removal: A Prospective Clinical Study

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Background

- Prefabricating retainers before the debond appointment improves patient experience, limits chair time, & limits overhead costs. This process requires the virtual removal of the fixed appliance from the digital dental model.
- A recent study was able to determine the accuracy of virtually removing brackets in Meshmixer® software to be 0.12-0.33mm, which was determined to be accurate for the fabrication of orthodontic retainers[1]
- Virtual attachment removal (VAR) has never been studied despite its relevance in prefabricating retainers and during refinements in clear aligner therapy .

Objectives

- Measure the accuracy of virtual attachment removal (VAR)
- Compare VAR of different maxillary teeth types
- Compare VAR of teeth with one vs. two attachments
- **Hypothesis**: VAR will be accurate enough for the fabrication of clinically acceptable (0-0.3mm) orthodontic retainers

Methods

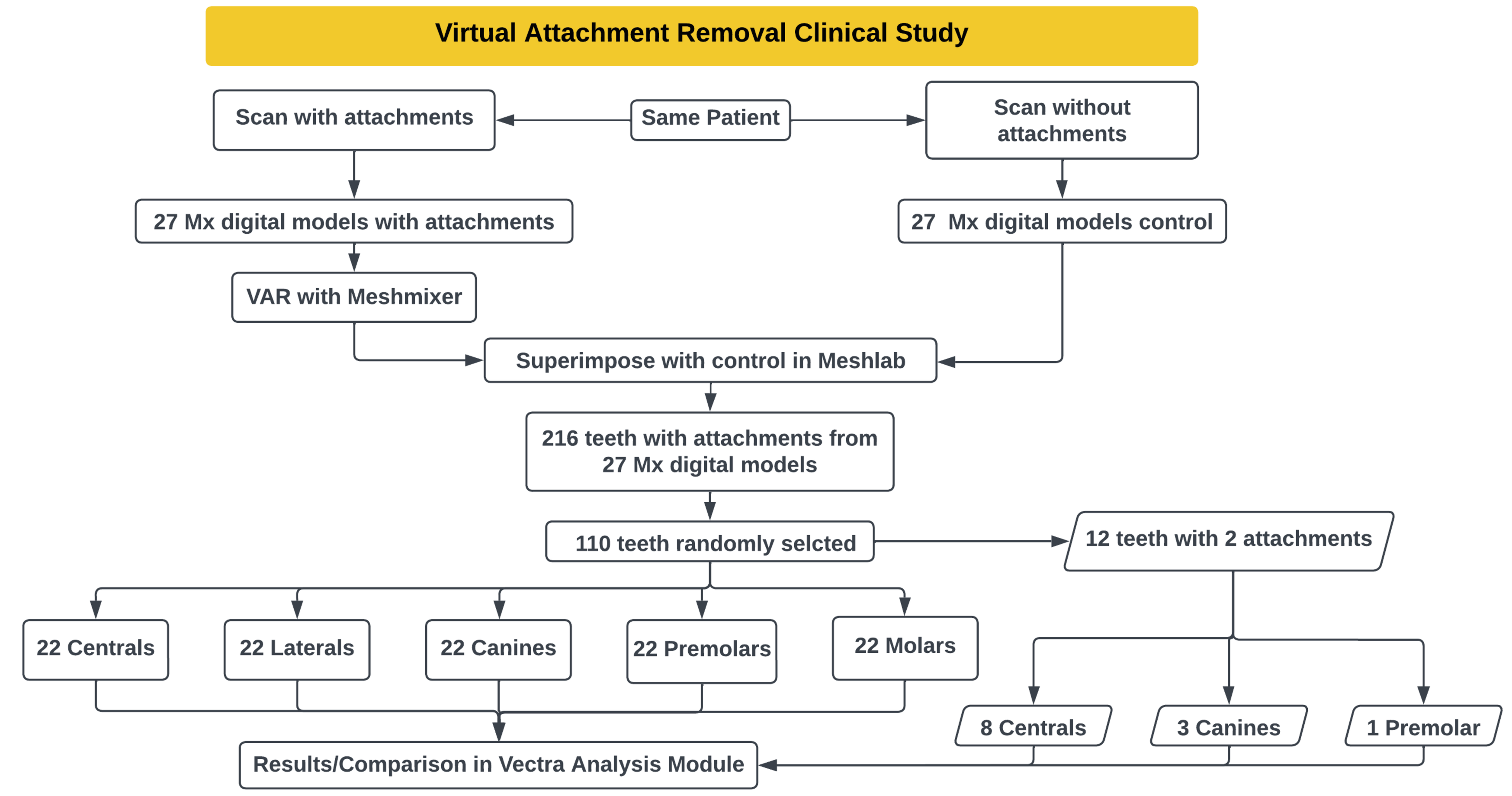

Figure 1: Workflow of VAR procedures

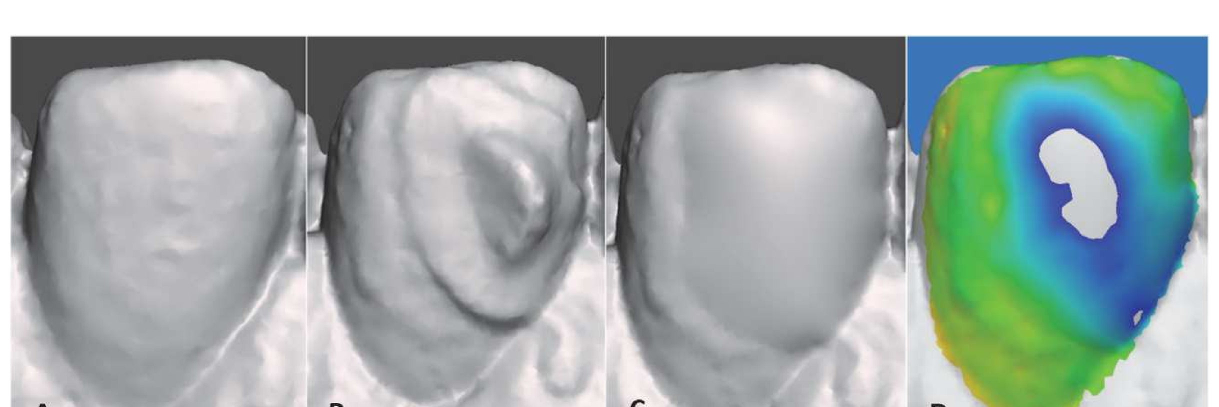

Figure 2: A, Control digital model group of lateral incisor without an attachment; **B**, Same lateral incisor with an attachment before VAR. Notice the position of the attachment is not in the center of the tooth and the extensive amount of excess composite flash extending in all directions; **C**, surface of the tooth after VAR. There is a noticeable protrusive bulge from where the attachment and flash were removed; **D**, after VAR the entire facial surface of the lateral incisor is being measured in VAM using the color surface by distal tool. A color-coded map is generated with a visualization range of ± 300 µm. Blue hues indicate positive surface change, green hues indicate little to no surface change, red and yellow hues indicate negative surface change, and white hues indicate surface change greater than 300 µm.

Results

- The intra-rater reliability was determined to be high (>0.98)
- No statistically significant difference among tooth types with minimum, maximum, or root mean square (RMS) values.
- No statistically significant difference seen among teeth with one vs two attachments.
- RMS range of 0.071±0.088 - 0.095±0.101mm
- 75.7% of the surface changes resulted in insufficient attachment removal

Table 1: Descriptive statistics of results given as median ± IQR. Different letters (in the same column) indicate significant differences between groups (P<0.05) (Kruskal-Wallis test)

Tooth Type	Min	Max	RMS
Central	-0.068±0.058[a]	0.182±0.201[a]	0.071±0.088[a]
Lateral	-0.063±0.077[a]	0.199±0.171[a]	0.077±0.072[a]
Canine	-0.060±0.041[a]	0.212±0.294[a]	0.073±0.133[a]
Premolar	-0.069±0.065[a]	0.188±0.154[a]	0.078±0.050[a]
Molar	-0.090±0.096[a]	0.279±0.270[a]	0.095±0.101[a]
P-Value	0.282	0.493	0.425

Table 2: Descriptive statistics of teeth with one or two attachments given as median ± IQR. Different letters (in the same column) indicate significant differences between groups (Kruskal-Wallis test) (P<0.05)

Attachments	Min	Max	RMS
1	-0.070±0.71[a]	0.214±0.252[a]	0.077±0.094[a]
2	-0.063±0.047[a]	0.214±0.133[a]	0.074±0.048[a]
P-Value	0.638	0.73	0.508

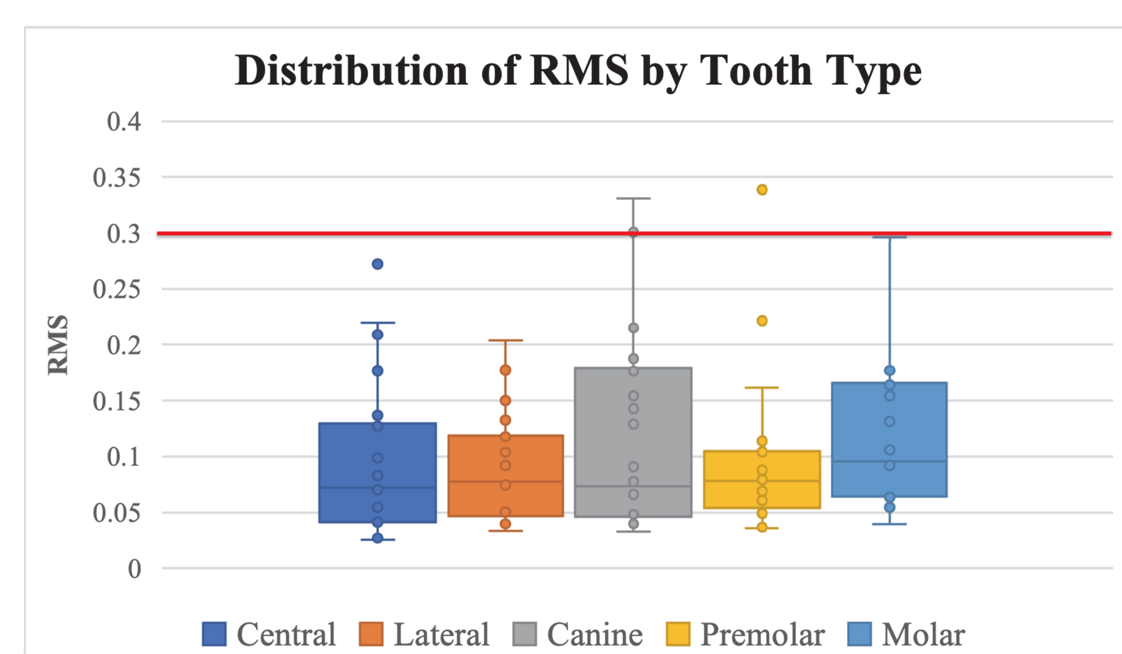

Figure 3: Box and whisker plot showing the distribution of RMS values by tooth type along with individual data points. The red line at 0.3mm indicates the level of clinical significance.

Table 3: The number and percentage of teeth whose measured minimum, maximum, and RMS values fall within the acceptable range of clinical accuracy (-0.3 to +0.3mm). Non-acceptable is any value outside the acceptable range.

Metric	Acceptable	Not Acceptable
Minimum	110 (100%)	0 (0%)
Maximum	75 (68.2%)	35 (31.8%)
RMS	107 (97.3%)	3 (2.7%)

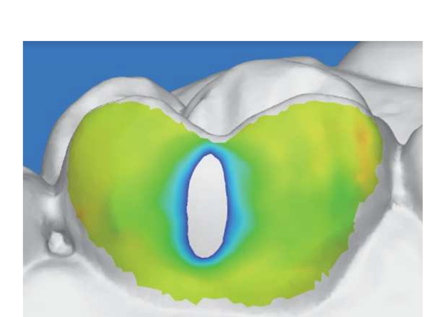

Figure 4: Buccal surface differences measured in the color surface by distance tool in Vectra. The white hue over the buccal groove in a common finding with VAR as Meshmixer® is not able to replicate the original anatomy if VAR was completed in that area.

Discussion

- RMS was the primary metric as it best represents the overall magnitude of surface changes regardless of + or - direction.
- There was a tendency for less accurate attachment removal in the molars. This is likely due to gingival margins covering more of the tooth & the presence of the buccal groove, which Meshmixer® was not able to replace (Figure 4)
- The largest RMS values were associated with attachments that had excess composite flash and/or located along the perimeter of the buccal surface, while the smaller RMS values have little flash.
- **Clinical implications for retention:**
  - The tendency for inadequate attachment removal may lead to a looser fitting retainer but is unlikely to have issues with the retainer seating completely.
  - Larger minimum values may lead to a tighter or ill-fitting retainer with the possibility of unwanted force & tooth movement. However, there were no teeth in this study that had minimum values that were clinically unacceptable.
- **Future research:** investigate thermoform retainer fit and comparison of VAR with different software.

Limitations

- Meshmixer® sculpting tools were not used on the digital models, which could have influenced accuracy.
- Conclusions must be limited to the maxillary arch.
- RMS values may appear artificially lower as the entire buccal surface of the tooth was measured rather than the specific location of VAR.

Conclusions

- Using Meshmixer® for VAR is precise enough to be used to make orthodontic retainers & is not affected by the number of attachments.
- There was an overall tendency for insufficient attachment removal.
- VAR accuracy may be influenced by size and location of attachments/flash.

Reference

1. Marsh K, Weissheimer A, Yin K, Chamberlain-Umanoff A, Tong H, Sameshima GT. Three-dimensional assessment of virtual bracket removal for orthodontic retainers: A prospective clinical study. Am J Orthod Dentofacial Orthop. 2021;160(2):302-311. doi:10.1016/j.ajodo.2020.09.027