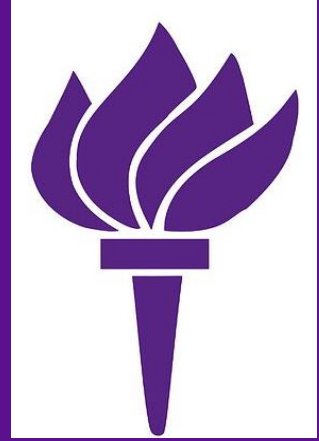




# OPTIMIZING INTRA-ORAL SCAN PATTERNS FOR TAPERED AND SQUARE ARCH FORMS

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## Introduction

Dental arch forms exhibit significant variation among individuals, with the tapered and square arch forms accounting for approximately 40% and 20% of the population,<sup>1</sup> respectively. These arch types are frequently encountered in orthodontic and restorative dental practices and are often associated with dental crowding or unfavorable occlusal relationships. Such anatomical characteristics present unique challenges in achieving accurate digital impressions, particularly when using intraoral scanning technologies.<sup>2</sup>

Among various scanning techniques, the Occlusal–Lingual–Buccal (OLB) scan pattern is widely regarded as the clinical gold standard, followed by zigzag (ZZ) and other alternative patterns.<sup>3</sup> However, despite its widespread adoption, there is a notable lack of literature comparing the efficacy and accuracy of these scanning patterns in relation to specific dental arch forms. Therefore, a systematic investigation into the performance of different scan patterns across varying arch forms—particularly the tapered and square types—is necessary to improve digital impression accuracy and support the integration of intraoral scanning into contemporary digital dentistry workflows.

This pilot study seeks to address this gap by evaluating the relationship between dental arch form and the effectiveness of various intraoral scanning patterns, with the goal of establishing evidence-based guidelines to enhance clinical outcomes and streamline CAD/CAM integration in prosthodontics and restorative dentistry.

## Purpose

To compare the influence of different scan patterns, including (1) Occlusal-Lingual Buccal (OLB), (2) Zigzag (ZZ) and (3) Dual scan (A combination of ZZ and OLB/ DUAL) in the accuracy of scans obtained for tapered and square dentate arches.

## Materials and Methods

Two maxillary typodonts (tapered and square) were digitized with a high-precision desktop scanner (E4 Lab Scanner, 3Shape®) to generate reference models. Each typodont was then scanned 20 times (n = 20) with an Emerald S intra-oral scanner (Planmeca®) using the OLB, ZZ and DUAL scan patterns. The DUAL is a combination scan pattern integrating OLB method with localized zigzag pattern. The Study was done with comparison and scans as per Table 1. STL files were superimposed on the references in Geomagic Control X, and Root-Mean-Square (RMS) deviation was calculated. Data normality was verified with the Shapiro–Wilk test. A two-way ANOVA followed by Tukey post-hoc comparisons ( $\alpha = 0.05$ ) evaluated the effects of arch form and scan pattern.

STL files were superimposed on the references in Geomagic Control X, and Root-Mean-Square (RMS) deviation was calculated. Data normality was verified with the Shapiro–Wilk test. A two-way ANOVA followed by Tukey post-hoc comparisons ( $\alpha = 0.05$ ) evaluated the effects of arch form and scan pattern.

| Group 1 | Control | Tapered | Desktop | OLB  |
|---------|---------|---------|---------|------|
| Group 2 |         | Square  |         |      |
| Group 3 | Test    | Tapered | IOS     | ZZ   |
| Group 4 |         |         |         | DUAL |
| Group 5 |         |         |         | OLB  |
| Group 6 | Test    | Square  | IOS     | ZZ   |
| Group 7 |         |         |         | DUAL |
| Group 8 |         |         |         | DUAL |

Table 1: Study Groups



Figure 1: Emerald S intra-oral scanner (Planmeca®)



Figure 2: Taper and Square Arch Forms

## Results

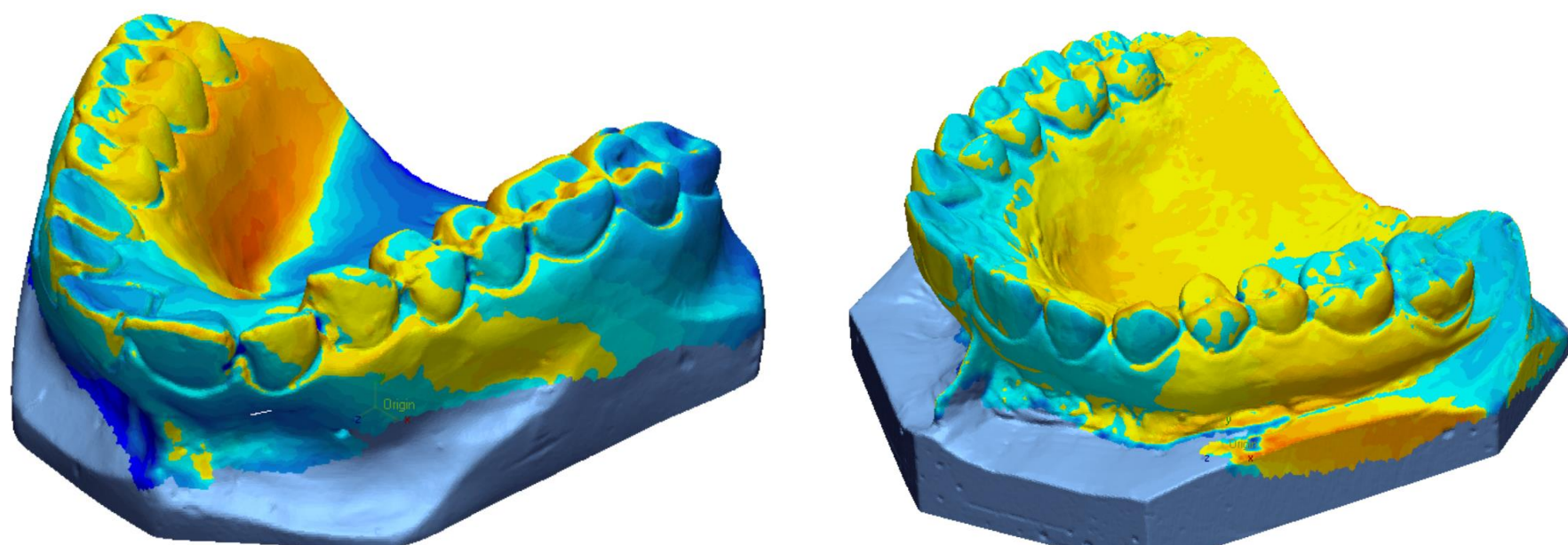


Figure 3: Heat Map Analysis of OLB scan pattern

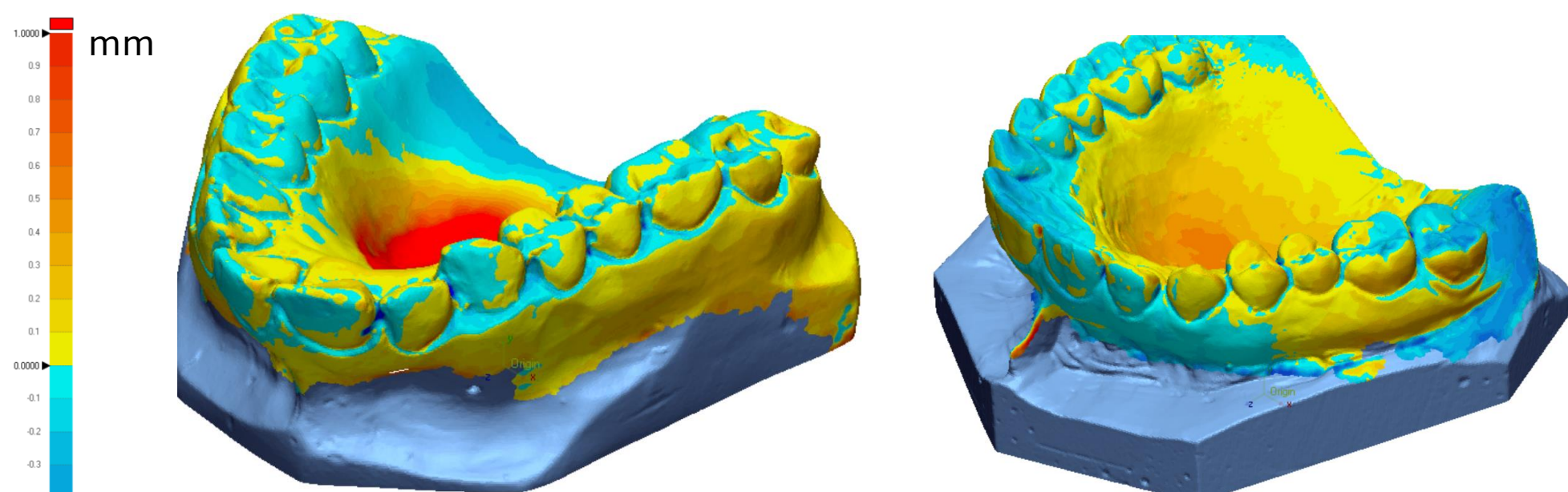


Figure 4: Heat Map Analysis of ZZ Scan pattern

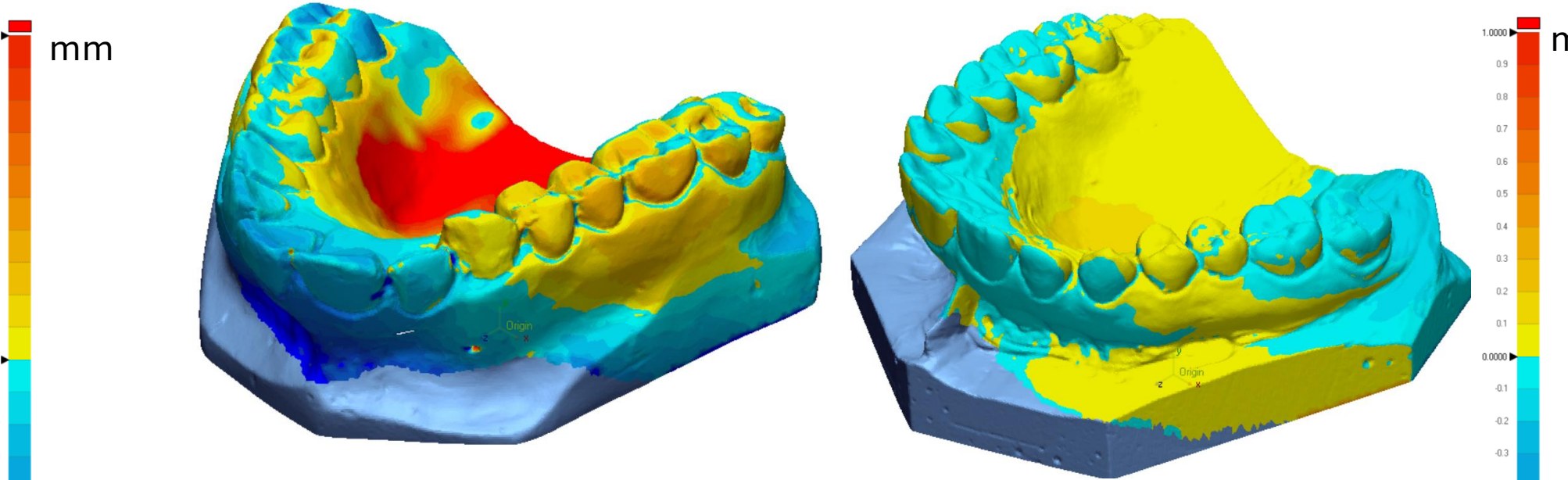


Figure 5: Heat Map Analysis of DUAL Scan pattern

Arch form significantly influenced scan accuracy ( $F = 9.59$ ,  $p = 0.002$ ); square arches showed greater RMS error than tapered arches. Scan pattern ( $F = 0.83$ ,  $p = 0.436$ ) and the arch-form interaction ( $F = 0.04$ ,  $p = 0.959$ ) were not significant. In the descriptive analysis, the ZZ scan pattern yielded the lowest mean RMS values, while OLB produced the highest.

| Scan Patterns | Arch Forms | Mean                 | 95% CI |
|---------------|------------|----------------------|--------|
| OLB           | Square     | 0.075 <sup>a,b</sup> | 0.009  |
|               | Taper      | 0.067 <sup>a,b</sup> | 0.007  |
| ZZ            | Square     | 0.071 <sup>a</sup>   | 0.007  |
|               | Taper      | 0.061 <sup>b</sup>   | 0.007  |
| DUAL          | Square     | 0.074 <sup>a,b</sup> | 0.007  |
|               | Taper      | 0.065 <sup>a,b</sup> | 0.007  |

Table 2: The mean value comparison of different scan patterns and arch forms with noted difference only in ZZ Scan pattern. Different letters imply statistical difference.

| Arch Forms | Mean               | 95% CI |
|------------|--------------------|--------|
| Square     | 0.074 <sup>a</sup> | 0.004  |
| Taper      | 0.064 <sup>b</sup> | 0.003  |

Table 3: Comparison of arch forms independent of scan patterns with difference noted. Different letters imply statistical difference.

| Scan Patterns | Mean               | 95% CI |
|---------------|--------------------|--------|
| OLB           | 0.071 <sup>a</sup> | 0.005  |
| ZZ            | 0.066 <sup>a</sup> | 0.004  |
| DUAL          | 0.069 <sup>a</sup> | 0.004  |

Table 4: Comparison of scan patterns independent of arch forms Different letters imply statistical difference.

## Discussion

The Tukey post-hoc tests demonstrated that the OLB approach might be a slightly more reliable method for achieving accurate digital impressions, although not statistically significant. This finding suggests that the optimal scan pattern is not universal but is dependent on the type of arch being scanned. For instance, while the OLB pattern may be preferred, its performance could be notably different when applied to a full-arch scan versus a quadrant scan, and this interaction warrants further investigation. The clinical relevance of this interaction is important, as it underscores the importance of practitioners tailoring their scanning technique to the specific clinical situation. The main statistical difference for arch form implies that square arch forms are harder to scan than tapered. This implies that the arch form itself may be an independent predictor of scan accuracy. Using the scan pattern with the highest reproducibility might help navigate certain hardships. Heat maps showed greater discrepancies in the palatal regions across all arch forms, with more extensive red and yellow zones indicating localized error. This suggests that there is a greater challenge in accurately digitizing the palate.

In summary, the findings suggest that the choice of scan pattern is a critical factor influencing the trueness and precision of digital impressions. There is no one accurate scan pattern though OLB has the least errors. However, the significant interaction effect between scan pattern and arch form indicates that the best clinical outcomes are achieved by a tailored approach, where the scan pattern is selected to complement the specific arch form being scanned. These results have immediate clinical application in helping clinicians optimize their scanning protocols to improve the quality of digital workflows and ultimately, the fit and longevity of indirect dental restorations.

## Conclusion

Square maxillary arches are more challenging to digitize accurately than tapered arches. Within the scan patterns tested, changing the scan pattern (OLB, ZZ, DUAL) did not produce a statistically significant difference in scan trueness.

## References

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