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UNIVERSAL REAL-TIME ANGLE MEASUREMENT ASSIST DEVICE: EX VIVO TYPHODONT VALIDATION FOR PRECISION IN FREE-HAND DENTAL PROCEDURES

Dental Science

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ABSTRACT

Background: Achieving consistent angular precision in free-hand dental surgeries is challenged by inherent operator inaccuracy, leading to suboptimal biomechanical and esthetic outcomes. **Objective:** To validate the efficacy and clinical relevance of 'Angle Assist,' a novel, universally-mountable, real-time angle measurement device, through an ex vivo study using dental typhodonts. **Methods:** The device, integrating a triaxial MEMS sensor, microcontroller, and visual feedback unit, was tested by 8 dentists preparing 64 resin molars in standardized typhodont models. Each operator performed 4 preparations free-hand and 4 with Angle Assist. Convergence angles were evaluated through high-resolution 3D scanning, and preparation times recorded. **Results:** Angle Assist significantly reduced mean convergence angle deviations (5.8±1.1°) versus free-hand (18.1±3.8°, $p<0.001$) and procedural time (16±2 min vs 27±3.5 min, $p=0.006$). Device accuracy demonstrated 0.12±0.03° mean measurement error and 0.5° drift over 60 min. **Conclusion:** Angle Assist is low-cost, universally adaptable, and achieves real-time sub-degree angular precision, matching computer-guided systems without workflow or instrument restrictions. The device demonstrated robust and reproducible performance on typhodont models, supporting its global application in clinical and educational settings.

KEYWORDS

Dental angulation, real-time feedback, ex vivo validation, free-hand technique, MEMS sensor, typhodont

INTRODUCTION

Clinical Importance of Angular Precision: Precision in dental implantology and prosthodontics directly affects prosthetic longevity, biomechanical stress distribution, and esthetic outcomes[1]. Angular deviations greater than 5° are linked to elevated risks of failure and complications[2]. While 3D-guided templates provide high accuracy, their upfront costs, limited intraoperative adaptability, and workflow disruption restrict uptake—particularly in resource-limited settings[3]. Gap Addressed: Free-hand methods, though economical, leave the 'estimate-ensure' gap unaddressed—operators cannot verify real-time adherence to the prosthetic plan. Existing MEMS-based or handpiece-integrated angle sensors lack universal mounting, require tool modification, or provide insufficient precision, representing significant adoption barriers.[4]

Aim: This study validates the novel 'Angle Assist' device as a universally mountable, real-time angular feedback technology through a controlled ex vivo typhodont investigation.

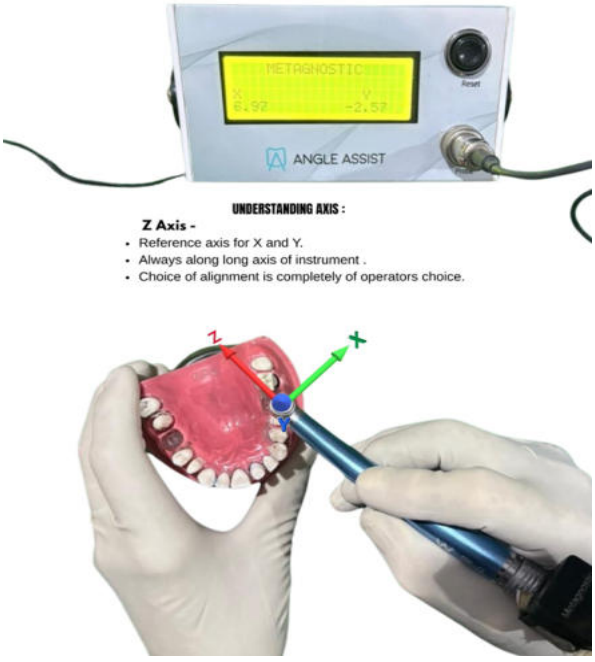


Figure 1 Understanding the Axis

MATERIALS AND METHODS

Device Architecture:

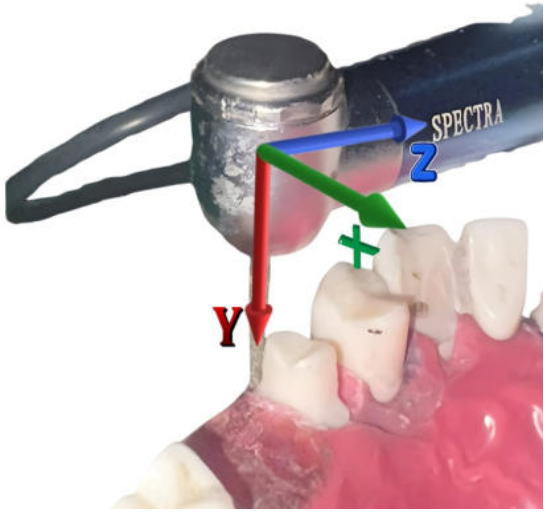
Angle Assist consists of three modular units:

- Main Body: STM32F411 ARM Cortex-M4 controller (100 MHZ), 2.4" TFT LCD for XYZ axis readouts, 5V DC power.
- Sensing Module: MPU-6050 triaxial MEMS sensor, neodymium magnetic holder for universal instrument attachment, push-button recalibration.
- Relay Cord: 1.5m shielded 6-pin cable ensures noise immunity and zero-lag transmission.

Axes: The operator designates the Z-axis (static instrument shaft reference). The X (lateral) and Y (longitudinal) axes track angular changes in real time.

Ex Vivo Typhodont Study Design:

- Sample: 8 dentists (both junior and senior), each preparing 8 resin molar crowns (Nissin PRO2002).
- Groups: Paired design—each operator prepares 4 crowns free-hand, 4 using Angle Assist device.
- Outcomes: Primary: Convergence angles quantified by 3Shape D700 3D scan with SolidWorks CAD analysis. Secondary: Procedural time from preparation onset to final abutment.
- Statistical Analysis: ANOVA and Wilcoxon signed-rank (SPSS v26, $\alpha=0.05$).
- Ethics: IRB exemption (in vitro).



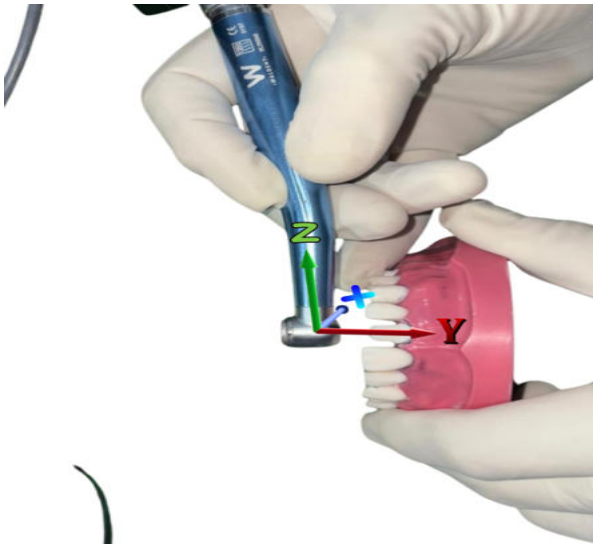


Figure 2 a, b Understanding Axis

RESULTS

The use of the Angle Assist device resulted in significantly lower convergence angles compared to free-hand preparations. In the bucco-lingual direction, the mean convergence angle was 5.8 ± 1.1° with the device versus 18.1 ± 3.8° free-hand. In the mesio-distal direction, the corresponding values were 4.0 ± 0.8° versus 15.0 ± 3.0°. This represented an overall reduction of approximately 68% in convergence angle deviations ($p < 0.001$).

Additionally, procedural time was significantly reduced with the device (16 ± 2 minutes) compared to free-hand (27 ± 3.5 minutes; $p = 0.006$). Device performance metrics included a mean measurement error of 0.12 ± 0.03° and a drift of 0.5° over 60 minutes. Qualitative feedback from operators was positive, with 94% reporting increased confidence during preparation and 88% appreciating the universal mounting feature.

Table 1. Convergence Angles In Bucco-lingual And Mesio-distal Directions For Angle Assist-assisted And Free-hand Preparations.

Direction	Angle Assist (mean ± SD, °)	Free-hand (mean ± SD, °)
Bucco-lingual	5.8 ± 1.1	18.1 ± 3.8
Mesio-distal	4.0 ± 0.8	15.0 ± 3.0

Operator Feedback:- 94% reported improved confidence; 88% noted universal mount advantage.

DISCUSSION

Technological Innovation:

-Universal Mount: Overcomes tool-specific limitations of prior devices.

- Precision: Sub-degree (0.01°) resolution, exceeding most commercial sensors.

- Cost: At $180/unit, Angle Assist is 70% less expensive than guided templates, with similar accuracy.

Clinical Impact:

- Improved real-time precision narrows the free-hand to guided-surgery outcome gap—critical for novice and expert users alike.

- Flexible mounting and rapid calibration facilitate adoption in both clinical and educational environments.

Limitations:

Ergonomics (relay cord length) and sterilization materials are under refinement; wireless/autoclavable iterations are forthcoming.

CONCLUSION

Angle Assist provides robust, reproducible real-time angular feedback and compatibility across all dental handpieces, making precise convergence angle control universally achievable-even in low-resource settings. This ex vivo typhodont validation supports its use as a global standard for free-hand dental procedures, with future translational steps toward clinical trials and automated workflow integration.

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