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Original Article

Influence of Salivary Viscosity on the Accuracy of Two Intraoral Scanners with Different Scanning Principles: A Comparative *in vitro* Study

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Abstract

Background: Moisture control is critical for intraoral scanning accuracy. This study evaluates how salivary viscosity influences the trueness and precision of two intraoral scanners with different scanning principles.

Materials and Methods: A mandibular jaw model was scanned under 3 conditions: dry condition without saliva, wet condition with low-viscous saliva and with high viscous saliva. Two scanners – Shining 3D (optical triangulation principle) and Trios 3 (confocal microscopy principle) – were used to analyse these conditions. A total of 10 scans were performed for each group. The root mean square error was calculated using Geomagic Control 2015, and data were analyzed using analysis of variance and Tukey's honestly significant difference ($\alpha = 0.05$).

Results: Higher viscosity saliva significantly reduced scanning accuracy. Optical triangulation consistently outperformed confocal microscopy. Significant interactions were found between scanner type and salivary condition ($P < 0.05$).

Conclusion: Salivary viscosity influences scan quality. Confocal microscopy is more resistant to viscous interference than optical triangulation. Scanner selection should consider oral moisture conditions for optimal prosthodontic outcomes.

Key words: Confocal microscopy, Digital impression, Intraoral scanner, Optical triangulation, Precision, Salivary viscosity, Trueness

INTRODUCTION

Conventional dental impression techniques involve the use of trays and impression materials such as alginate or polyvinyl siloxane to capture the oral structures. These methods are often associated with patient discomfort, longer working times, and potential for distortion during material setting or cast pouring.[1]

Intraoral scanners (IOS) have become integral to digital dentistry, streamlining workflows and enhancing patient comfort.[2] Despite technological advancements, one persistent challenge in clinical use is the moist environment of the oral cavity, wh A mandibular jaw model was scanned under 3 conditions: dry condition without saliva, wet condition with low-viscous saliva and with high viscous saliva ere saliva acts as a variable affecting scan fidelity. Although moisture is a known interference, limited data exist on how the viscosity of this moisture alters scanner performance.[3]

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Saliva varies in viscosity due to physiological, pharmacological, and pathological factors. Thin, watery saliva may quickly drain or evaporate, whereas thicker, more viscous saliva adheres to the tooth surface, forming a persistent layer that may distort reflected or transmitted light.[4] These differences may lead to systematic inaccuracies in digital impressions, particularly when high-precision outcomes are required.

Objectives

- To evaluate and compare the effect of low viscosity and high viscosity saliva solutions on the trueness and precision of two scanners with different scanning principles
- To compare the performance of two IOSs based on different scanning principles (optical triangulation and confocal microscopy) under wet (low and high viscosity) conditions.

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MATERIALS AND METHODS

Test Conditions

- Dry (control)
- Low-viscosity (low-viscosity artificial saliva solution) [Figure 1]
- High-viscosity (mucin-based artificial saliva solution) [Figure 2].

Artificial saliva solution.

Box

1. Cylindrical box with a hole at the bottom
2. Cuboidal-shaped box.

Scanners

- Shining 3D (optical triangulation)
- Trios 3 (confocal microscopy).

Study Design and Setting

An *in vitro* comparative study was conducted in the Departments of Prosthodontics and Oral Medicine & Radiology, KMCT Dental College.

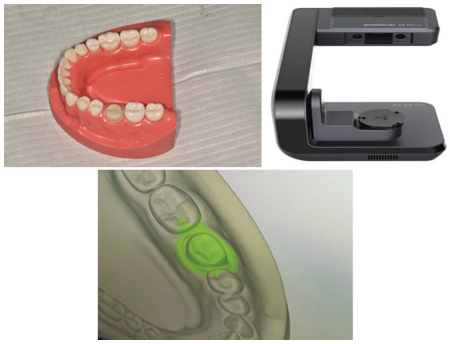
Sample Size

Calculated using the formula $n = ([Z\alpha/2 + Z\beta]^2 \times 2\sigma^2)/d^2$, with $\sigma = 0.26$ mm and $d = 0.3$ mm. Result: 10 samples/group.

Sample Grouping

Group 1 (Control)	Dry tooth surface.
Group 2	Tooth surface wetted with low-viscosity saliva solution.
Group 3	Tooth surface wetted with highviscosity saliva solution.

Scanning Protocol



Scanning Procedures

Two different IOSs (Shining 3D and Trios 3) were calibrated according to the manufacturers' instructions. To obtain a reference scan, the mandibular jaw model was scanned [Figures 3 and 4]using a high-accuracy laboratory scanning device [Figure 5] (Shining 3D). The scan data obtained was exported in standard tessellation language (STL) format.

The mandibular jaw model was then scanned using the two different IOSs:

- Shining 3D (Software version: [V3.5.6.8], Shining 3D, Hangzhou, China)
- Trios 3 (Software version: 19.2.5, 3 Shape, Copenhagen, Denmark).

Two types of solutions were tested in this study: High-viscosity saliva solution [Figure 6] (prepared using mucin-based solutions) and low-viscosity saliva solution [Figure 7]. The intraoral scanning was done under the following conditions:

- Optical triangulation principle with high viscosity saliva solution,
- Optical triangulation with low-viscosity saliva solution,
- Confocal microscopy principle with high viscosity saliva solution,
- Confocal microscopy principle with low-viscosity saliva solution.

-Step:
A hole is created at the bottom (5 mm) of a cylindrical box, which is then temporarily blocked using utility wax [Figure 8]. The Typodont model is placed in the cylindrical box, and high-viscosity saliva solution is poured into it up to a height of 4 cm from the bottom [Figure 9]. Once the box is filled to this level, the utility wax is removed, allowing the high-viscosity saliva solution to drain through the hole into a cuboidal box placed below [Figure 10]. The process continues until the liquid has completely drained, and the wetted model was left undisturbed for 1 min [Figure 11] before scanning with optical triangulation; this process was repeated 10 times.

The same procedure was repeated using a low-viscosity saliva solution. Each group was scanned 10 times using both optical triangulation and confocal microscopy principles. After completing all scans for one group (n = 10) using the optical triangulation principle, the mandibular jaw model was thoroughly dried with sterile paper towels and allowed to rest for 24 h before proceeding with the next set of scans using the confocal microscopy principle. In total, 40 samples were obtained and exported in STL format. Based on the scanning

condition (type of IOS and viscosity of the liquid used), the 40 virtual models were divided into four groups, each consisting of 10 scans.

Data Processing

Figures 12 and 13.

Optical Triangulation

Table 1.

Confocal Microscopy

Table 2.

All STL scans were compared against a reference model generated by a laboratory scanner. Trueness and precision were calculated.

Statistical Analysis

Statistical Package for the Social Sciences v25 was used. Shapiro–Wilk and Levene's tests assessed normality and variance. Analysis of variance with Tukey's honestly significant difference *post hoc* test evaluated differences ($P < 0.05$).

RESULTS

Tables 1 and 2 summarize the trueness of the mean and standard deviation of the root mean square (RMS) value under different conditions according to different scanning principles and the type of viscosity liquid used.

Trueness

Observations specific to the scanner high viscous condition for optical triangulation: RMS values varied between 0.112 and 0.977 μm; Mean trueness: 0.4398 μm; notable variability was noted, with one value approaching 1.0 μm.

- Low viscous condition: More constant and with less variance than high viscous condition; mean trueness: 0.2106 μm; RMS values varied between 0.101 and 0.551 μm. Confocal microscopy
- High viscous condition: • Mean trueness: 0.1134 μm • RMS values varied between 0.093 and 0.139 μm • Showed constant trueness and low deviation. Serious condition: • Mean trueness: 0.1149 μm • RMS values varied between 0.080 and 0.151 μm • Performance was extremely consistent across all samples.

Precision

- Table 3 presents the precision of the mean and standard deviation of the RMS values obtained under various conditions, categorized by scanning principle and the type of viscosity of the saliva solution used. The optical triangulation principle scanner demonstrated slightly better precision overall, particularly in low viscosity of the saliva solution.
- The confocal microscopy principle scanner showed higher mean precision values (i.e., lower precision), especially in low-viscosity saliva solution environments.

DISCUSSION

Intraoral scanning accuracy can be compromised by various oral fluids, particularly saliva. Saliva exists in two primary forms – serous and mucous – each with distinct properties that impact the scanning process differently. This document outlines how the physical and optical properties of these two types of saliva affect IOS performance.[5] This study confirms that salivary viscosity directly influences IOS accuracy. Higher-viscosity fluids create optical scattering, film irregularities, and persistent surface layers that interfere with light-based scanning.[6] These effects are more pronounced in scanners based on optical triangulation, which rely on clear reflection angles.

In contrast, confocal microscopy-based scanners minimize depth-of-field distortions and better isolate imaging planes, offering resilience against viscous interference.[5,6] Clinically, the choice of scanner should account for patient-specific moisture conditions, particularly when precision is critical for prosthodontic outcomes.

Table 1: Results of optical triangulation principles

	High Viscous			Low Viscous		
S/N	Samples	RMS (μm)	Theoretical overlap	Samples	RMS (μm)	Theoretical overlap
1	O-H-A	0.112441	100.00%	O-L-A	0.101055	100.00%
2	O-H-B	0.977263	100.00%	O-L-B	0.10999	100.00%
3	O-H-C	0.113483	100.00%	O-L-C	0.147857	100.00%
4	O-H-D	0.19105	100.00%	O-L-D	0.113105	100.00%
5	O-H-E	0.409407	100.00%	O-L-E	0.551046	100.00%
6	O-H-F	0.834863	100.00%	O-L-F	0.240447	100.00%

Table 2: Results of confocal microscopyprinciples

	High viscous			Low viscous	
S/N	Samples	RMS (μm)	Theoretical overlap	Samples	RMS (μm)
1	C-H-A	0.0936595	100.00%	C-L-A	0.151493
2	C-H-B	0.106839	100.00%	C-L-B	0.144233
3	C-H-C	0.137987	100.00%	C-L-C	0.1317
4	C-H-D	0.139229	100.00%	C-L-D	0.089653
5	C-H-E	0.105523	100.00%	C-L-E	0.092416
6	C-H-F	0.0969159	100.00%	C-L-F	0.0800774

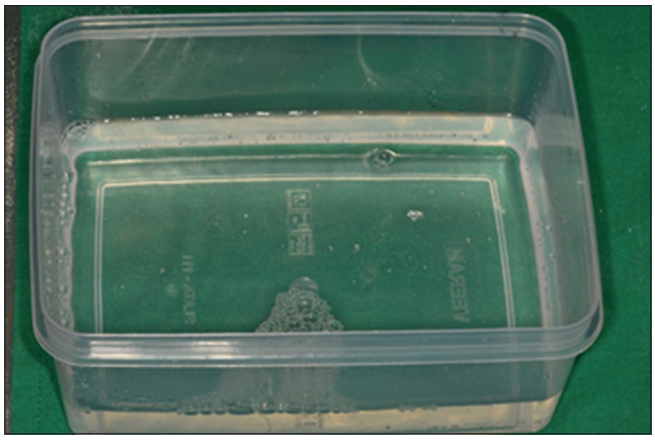


Figure 1: Low-viscosity saliva solution

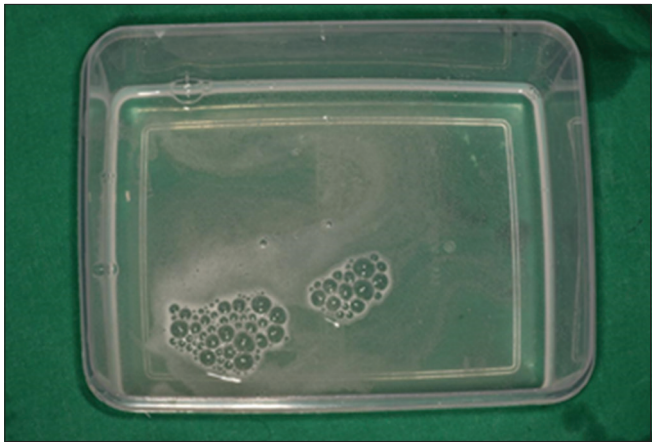


Figure 2: High-viscosity solution

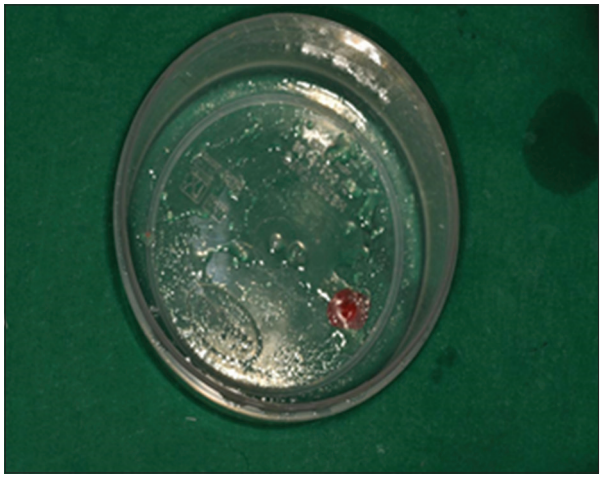


Figure 3: The hole in the cylindrical box was blocked with utility wax

Figure 5: The utility wax used to seal the hole was then removed, and the liquid was allowed to drain slowly from the small hole into the cuboidal box

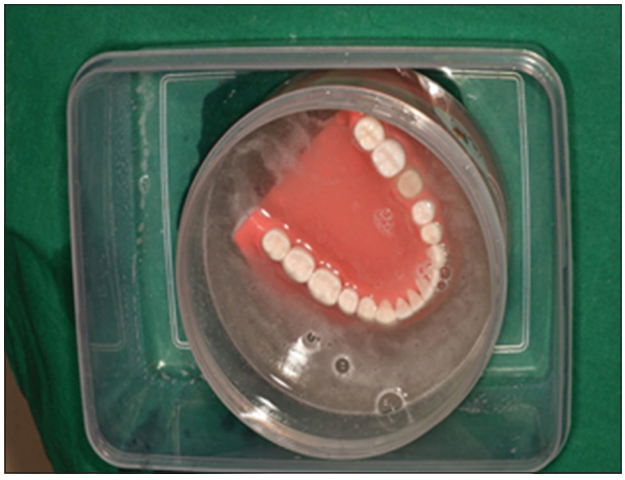


Figure 4: Liquid (high- and low-viscosity saliva solution) was slowly introduced from the corner of the cylindrical box until the mandibular jaw model was completely immersed

Table 3: Mean deviation precision group

Group	Mean precision (µm)
Optical triangulation principle with high-viscosity saliva solution	0.142 µm
Optical triangulation with low-viscosity saliva solution	0.140 µm
Confocal microscopy principle with high-viscosity saliva solution	0.160 µm
Confocal microscopy principle with low-viscosity saliva solution	0.170 µm

These findings also underline the importance of pre-scan fluid control strategies, such as suctioning, air-drying, or saliva-thinning agents, especially in high-risk patients. Serous saliva, being thin, clear, and easily displaced, causes minimal optical interference during intraoral scanning and typically maintains clinically acceptable accuracy.[7] Mucous saliva, being thick, sticky, and rich in mucins, significantly disrupts scan accuracy by scattering light, distorting surfaces, and trapping bubbles – especially affecting scanners reliant on optical triangulation.

Figure 6: The mandibular jaw model was then scanned

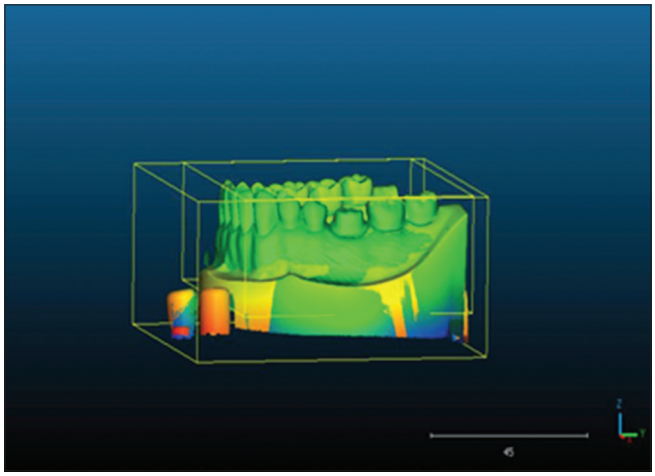


Figure 7: High-accuracy industrial computed tomography

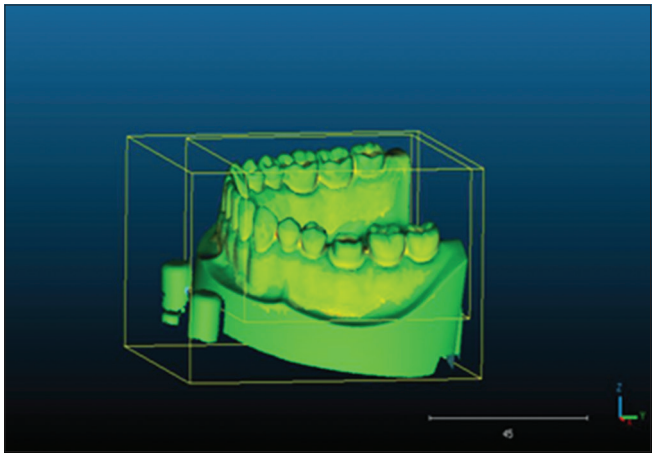


Figure 8: Precision was calculated by intra-group comparisons of the scan

CONCLUSION

Salivary viscosity has a significant impact on the accuracy and repeatability of IOSs. High-viscosity fluids increase scan error, particularly in posterior and interproximal regions. Confocal microscopy scanners showed greater resilience and accuracy in moist clinical environments.

Future studies should investigate real-time salivary behavior *in vivo*, exploring scanner performance during dynamic oral movements and under varying glandular secretions.

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ETHICAL APPROVAL

Not applicable (*in vitro* study).

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