# COMPARISONS OF FIDELITY IN THE DIGITIZATION AND 3D PRINTING OF VERTEBRATE FOSSILS

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## Introduction

Digitization and 3D printing have been underutilized tools in the field of paleontology due to the significant investments of time and money, as well as the low accuracy of 3D reproductions. However, as these technologies have advanced, the initial investment costs and the quality of printing have advanced significantly, making them more attractive as tools for paleontology research (e.g. Tschopp and Gordon, 2012; Rahman et al., 2012).

This study examines the fidelity of paleontological data during commonly utilized digitization techniques and reproduction on commercial 3D printer systems. Digital models created by projected structured-light scanning and triangulated laser-texture scanning were compared in order to determine the differences in fidelity between scanning methods (Mallison, 2011).

Additionally, these specimens were printed on different low-cost 3D printers and subsequently measured to determine differences in fidelity based on printer model and different printer settings. These measurements determine where and how much data is lost in both the digitization and reproduction processes.

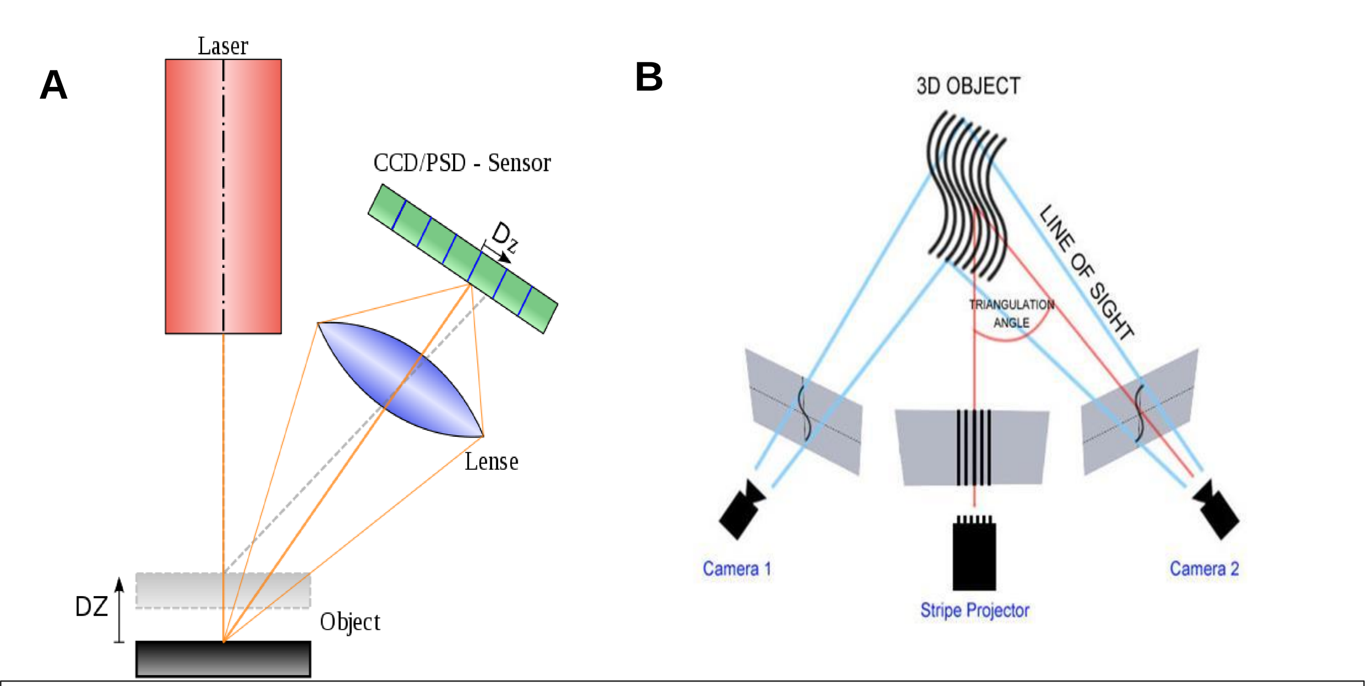


**Figure 1.** Schematic diagrams depicting A) the principles of laser texture scanning and B) the principles of structured-light scanning.

## Methods

High-resolution resin casts of a shed tooth from *Tyrannosaurus rex* (PR2081) and a dorsal osteoderm from a Cretaceous crocodilian (PR3703) were digitally scanned using two digitization technologies: triangulated laser texture scanning (Figure 1A) with a NextEngine 3D Laser Scanner and projected structured-light scanning (Figure 1B) with a 3D3 Solutions White Light Scanner. The resulting digital models were then 3D printed on two printers: an Up Mini and a Flashforge Creator Pro.

The resulting printed models were then compared and measured for potential deviation (Figure 2 A-C), and digital models were compared to determine the topographic deviation between each digitization technique (Figure 3 A-D).

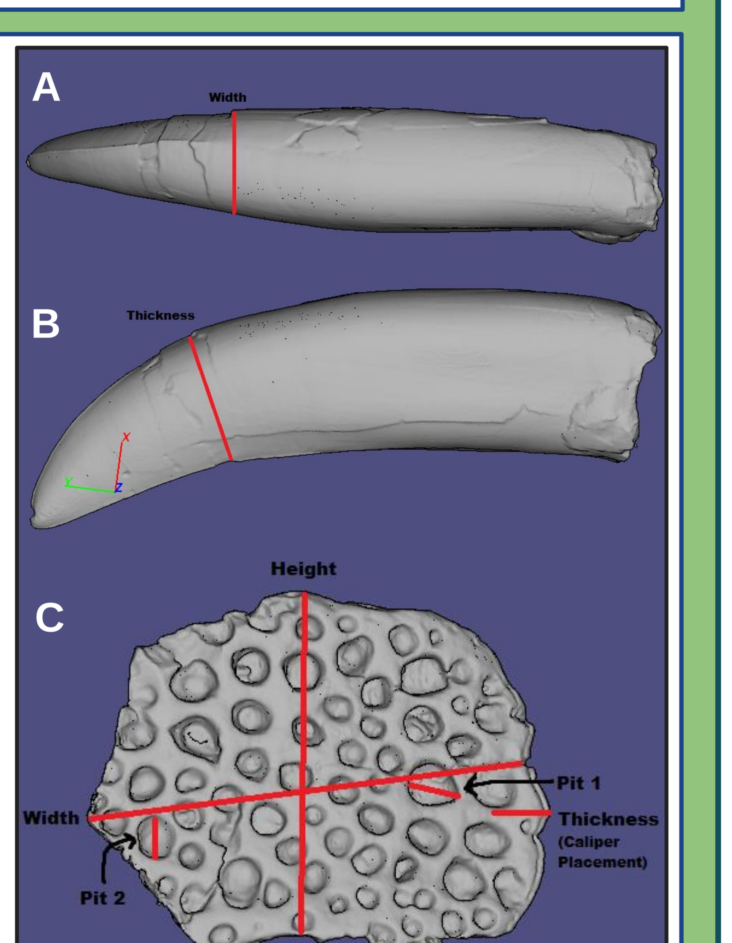


**Figure 2.** Illustrations depicting measurement parameters for 3D printed models of PR2081 (2A-B) and PR3703 (2C).

## Research Goal

This study explores where and to what degree information is lost in the digitization and additive manufacturing reproduction of fossil specimens to asses the reliablity of these technologies in paleontology research.

## Results of Digitization

Following the digitization of the specimens, a heat gradient map for each specimen was created that provides a visual depiction of the topographic deviances between models, with the structured-light scanned model as a solid green reference and the laser-texture scanned model overlain with gradient color that reflects the degree of variance (Figure 3 A-D). Additionally, volume and surface area data for each digital model were compared using a Two-tailed T-test analysis in order to determine the differences in model sizes between the two digitization techniques. Digital models created for PR2081 resulted in a 0.9808 *p*-value, and digital models for PR3703 resulted in a 0.6431 *p*-value, signifying that both digitization methods resulted in minimal topographic deviances that were not statisically significant.

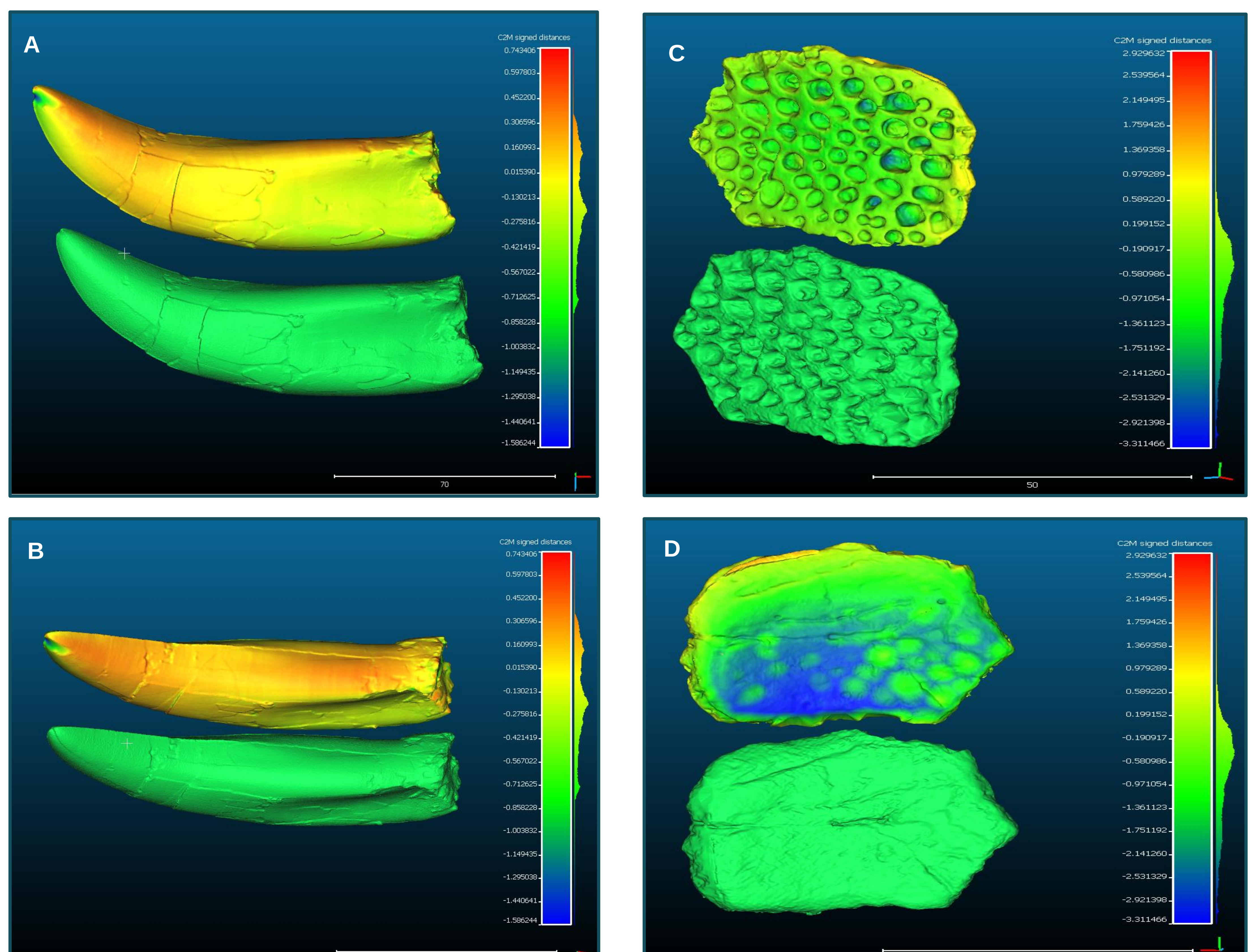


**Figure 3:** Heat diagrams depicting the topographic differences in digitized models between structured-light scans (solid green models) and laser texture scans (gradient-colored models) of PR2081 (3A & 3D), and PR3703 (3C & 3D).

**Table 1:** Two-tailed T-Test statistical analysis of digital models by model and scanning technique.

| Model | Scanner | Mesh Surf Meas (S) | Mean Tri Surf | Mesh Vol | Two-tailed P value |
|---|---|---|---|---|---|
| PR2081 | Laser-Texture | 12473.6 | 0.0124812 | 74857.5 | 0.9808 |
| | Structured Light | 12717.4 | 0.00653692 | 77163.2 | |
| PR3703 | Laser-Texture | 4970.17 | 0.00138549 | 4969.66 | 0.6431 |
| | Structured Light | 5056.68 | 0.00307501 | 9808.39 | |

## Results of 3D Printing

3D printed models of both specimens were microscopically measured at multiple easily correlatable topographic markers in order to determine the deviations in size between the digital models and their 3D printed counterparts. For PR2081, measurements were taken at prominent serrations easily correlated to all models (Figure 2 A, B). For PR3703, measurements were taken for all three spacial dimensions as well as the width of two prominent pits (Figure 2C).

The resulting print measurements were then compared with a Chi-Square statistical analysis, with resulting *p*-values of 1, indicating that differences in model dimensions attributed to the 3D printing process were not statistically significant.

**Table 2:** Chi-Square analysis of PR3703 3D printed models. A) Models printed from structured-light scanning, B) Models printed from laser-texture scanning. All measurements in mm.

A

| Printer | Length | Height | Thickness | Pit 1 | Pit 2 | | |
|---|---|---|---|---|---|---|---|
| Digital Model | 50.86 | 39.7 | 8.11 | 5.08 | 5.02 | DF | 8 |
| Flashforge | 52.49 | 39.93 | 7.93 | 5.06 | 4.53 | *p* value | 1 |
| UP Mini | 52.73 | 40.3 | 8.36 | 5.05 | 5.18 | | |

B

| Printer | Length | Height | Thickness | Pit 1 | Pit 2 | | |
|---|---|---|---|---|---|---|---|
| Digital Model | 53.26 | 41.92 | 5.04 | 5.92 | 5.25 | DF | 8 |
| Flashforge | 54.87 | 42.7 | 5.83 | 6.1 | 5.19 | *p* value | 1 |
| UP Mini | 55.57 | 43.7 | 5.89 | 6.23 | 5.5 | | |

**Table 3:** Chi-Square analysis of PR2081 3D printed models. A) Models printed from structured-light scanning, B) Models printed from laser-texture scanning. All measurements in mm.

A

| Printer | Thickness | Width | | |
|---|---|---|---|---|
| Digital Model | 50.86 | 39.7 | DF | 2 |
| Flashforge | 52.49 | 39.93 | *p* value | 0.9535 |
| UP Mini | 52.73 | 40.3 | | |

B

| Printer | Thickness | Width | | |
|---|---|---|---|---|
| Digital Model | 28.42 | 23.96 | DF | 2 |
| Flashforge | 31.3 | 24.2 | *p* value | 0.9712 |
| UP Mini | 31.17 | 24.38 | | |

## Discussion

Statistical analysis of size differences between the original resin casts and their digitally recreated and 3D printed counterparts demonstrated that no statistically significant information was lost either through digitization or 3D printing. Differences attributed to digitization and 3D printing were found to be on the order of 1mm or less.

Researchers found that digitization and 3D printing fidelity depends more on specimen morphology rather than the technology used. Thin specimens (<1cm in width) produced many digital artifacts during digitization, regardless of technology used.

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**References**

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