

# CS 3600

Summary from “Trueness and precision of 5 intraoral scanners in the impressions of single and multiple implants: a comparative in vitro study”

# Overview

## Article Name

“Trueness and precision of 5 intraoral scanners in the impressions of single and multiple implants: a comparative in vitro study”

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## Background

- Very few peer reviewed studies have evaluated the clinical efficacy of intraoral scanners in implantology.
- Even fewer studies compare the accuracy of the various intraoral scanners.
- This study compares the trueness and precision of five intraoral scanners, and determines which have both accurate and consistent results.



# What are Trueness and Precision?

## In this study:

**Trueness** is quantified by distances between generated model and reference model (smaller value means better trueness).

**Precision** is quantified by distances between repeatedly generated models (smaller value means better precision).

**Accuracy** is a combination of trueness and precision. An intraoral scanner must perform well in both trueness and precision tests to be considered “highly accurate.”



# Study Material and Methods

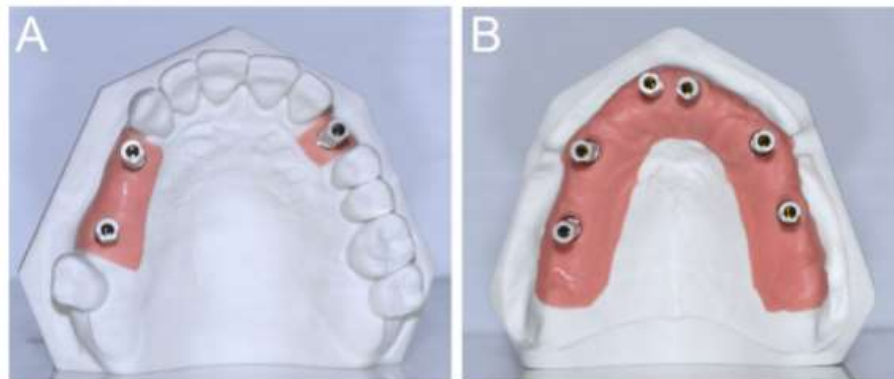
**10 scans** were performed by a single digital dentistry expert **per indication per intraoral scanner device** with a zig-zag technique in the same environmental conditions.

2 reference maxillary plaster models were used as a reference:

- A - Partially edentulous maxillary arch with:
  - Implant analog on tooth #23 (implant single support crown simulation)
  - Implant analog on teeth #14 & 16 (partial implant supported case simulation)
- B - Totally edentulous maxillary arch:
  - Implant analog on teeth #11, 14, 16, 21, 24 & 26 (fixed full arch implant supported denture simulation)

**Scanbodies used** : Megagen<sup>®</sup> PEEK scanbodies to enhance scans (no light reflection).

**Reference** : 3 scans made per indication with **Freedom UHD<sup>®</sup>** desktop scanner and superimposed in **Geomagic Studio 2012<sup>®</sup>** to validate the reference models.



# Implantology Intraoral Scanner Comparative Study

How do these intraoral scanners compare in accuracy?



TRIOS 3  
3shape



CS 3600  
Carestream  
DENTAL



EMERALD  
PLANMECA



OMNICAM  
Dentsply  
Sirona








DWIO  
dental wings



# Implantology Intraoral Scanner Comparative Study

## Summary of 5 Intraoral Scanners Used in the Study

| Scanner  | Producer                                    | Technology of Acquisition   | Powder | Color | System  |
|--|---|---|--------|-------|---|
|  <p>CS 3600</p>   | Carestream Dental,<br>Atlanta, Georgia, USA | Structured light-Active Speed 3D Video™                               | No     | Yes   | Proprietary files (CSZ), but also open formats (PLY, STL) immediately available                             |
|  <p>Trios 3</p>   | 3-Shape,<br>Copenhagen, Denmark             | Structured light –Confocal microscopy and Ultrafast Optical Scanning™ | No     | Yes   | Proprietary files (DCM) available, but possibility to export STL files via the new Trios on Dental Desktop® |
|  <p>Omniscam</p>  | Dentsply-Sirona,<br>York, Pennsylvania, USA | Structured light -Optical triangulation and confocal microscopy       | No     | Yes   | Proprietary files (CS3, SDT, CDT, IDT) are available, possible to export STL files via the Cerec Connect®   |
|  <p>DWIO</p>    | Dentalwings,<br>Montreal, Quebec, Canada    | Blue laser-Multiscan Imaging™ technology                              | No     | No    | Proprietary files (XORDER), but also open formats (STL) immediately available                               |
|  <p>Emerald</p> | Planmeca,<br>Helsinki, Finland              | Red, green and blue lasers-Projected Pattern Triangulation™           | No     | Yes   | Open formats (PLY, STL) immediately available   |



# Single Crown, Best Result in Trueness ( $\mu\text{M}$ )

Single crown: best result in trueness (standard deviation) in  $\mu\text{m}$ , for the 5 examined scanners, and the number of triangles composing each mesh.

*[Carestream Dental Note: Triangle number is not a measure of acquisition resolution or mesh quality. In fact, in having the best trueness with the smallest number of triangles, CS 3600 demonstrates the most efficient/optimal mesh generation (by placing more triangles in areas with more details and vice versa), with minimized mesh file size while maintaining accuracy.]*

**Best Result**



TRIOS 3



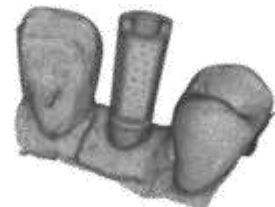
Deviation: 22  $\mu\text{m}$  (20)  
Triangles: 179,496



CS 3600



Deviation: 14  $\mu\text{m}$  (13)  
Triangles: 34,980



EMERALD



Deviation: 31  $\mu\text{m}$  (26)  
Triangles: 81,712



DWIO



Deviation: 23  $\mu\text{m}$  (21)  
Triangles: 68,281



OMNICAM



Deviation: 21  $\mu\text{m}$  (28)  
Triangles: 123,417



# Partial Prosthesis, Best Result in Trueness ( $\mu\text{M}$ )

Partial prosthesis: best result in trueness (standard deviation) in  $\mu\text{m}$ , for the 5 examined scanners, and the number of triangles composing each mesh.

*[Carestream Dental Note: Triangle number is not a measure of acquisition resolution or mesh quality. In fact, in having the best trueness with the smallest number of triangles, CS 3600 demonstrates the most efficient/optimal mesh generation (by placing more triangles in areas with more details and vice versa), with minimized mesh file size while maintaining accuracy.]*

**Best Result**



TRIOS 3



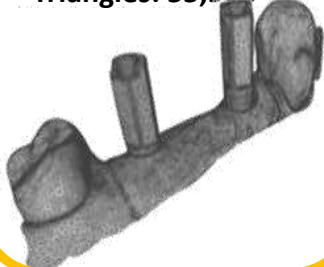
Deviation: 28  $\mu\text{m}$  (24)  
Triangles: 207,150



CS 3600



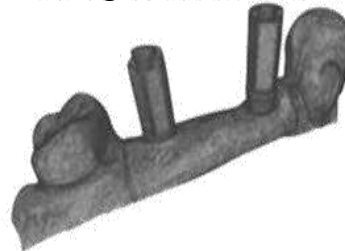
Deviation: 21  $\mu\text{m}$  (25)  
Triangles: 55,968



EMERALD



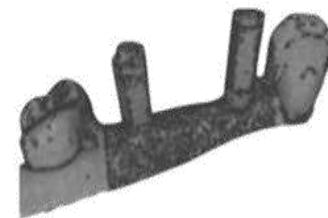
Deviation: 42  $\mu\text{m}$  (32)  
Triangles: 113,162



DWIO



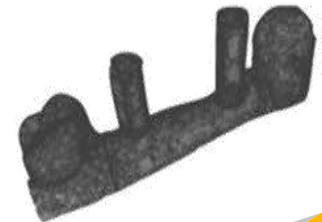
Deviation: 39  $\mu\text{m}$  (39)  
Triangles: 135,028



OMNICAM



Deviation: 29  $\mu\text{m}$  (32)  
Triangles: 192,967





# Full Arch, Best Result in Trueness ( $\mu\text{M}$ )

Full arch: best result in trueness (standard deviation) in  $\mu\text{m}$ , for the 5 examined scanners, and the number of triangles composing each mesh.

Best Result

[Carestream Dental Note: Triangle number is not a measure of acquisition resolution or mesh quality. In fact, in having the best trueness with the smallest number of triangles, CS 3600 demonstrates the most efficient/optimal mesh generation (by placing more triangles in areas with more details and vice versa), with minimized mesh file size while maintaining accuracy.]



TRIOS 3



CS 3600



EMERALD



DWIO



OMNICAM



Deviation: 37  $\mu\text{m}$  (44)  
Triangles: 326,696



Deviation: 32  $\mu\text{m}$  (49)  
Triangles: 83,735



Deviation: 57  $\mu\text{m}$  (58)  
Triangles: 178,507








Deviation: 73  $\mu\text{m}$  (64)  
Triangles: 227,491



Deviation: 47  $\mu\text{m}$  (55)  
Triangles: 322,929



# Mean Trueness/Standard Deviation

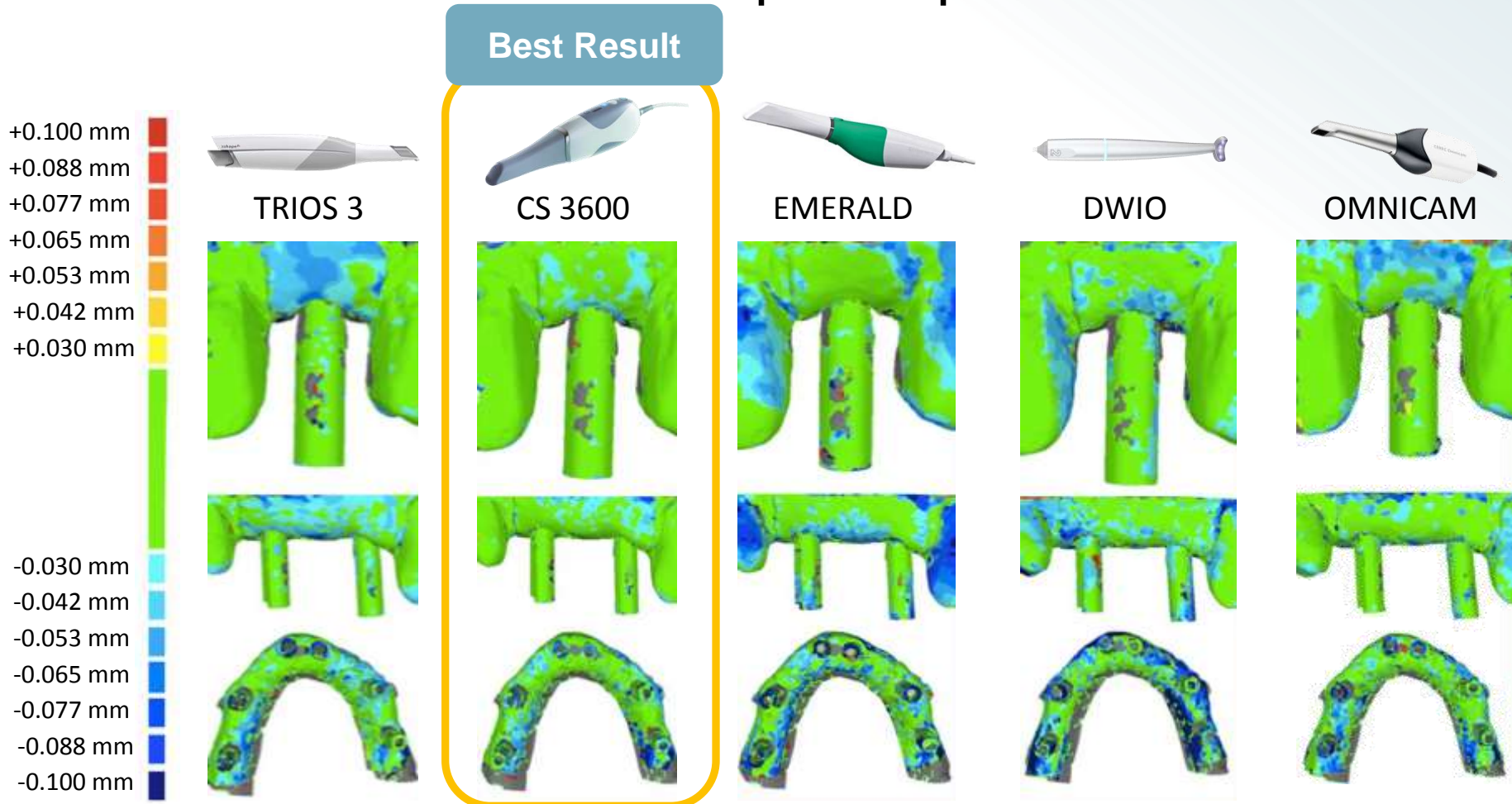
| Scanner   | Single Crown<br>Mean ± SD      | Partial Prosthesis<br>Mean ± SD | Full Arch<br>Mean ± SD         | p-value <sup>1</sup> |
|---|--------------------------------|---------------------------------|--------------------------------|----------------------|
| <br>Trios 3    | 22.3 ± 0.5 <sup>†</sup>        | 28.5 ± 0.5 <sup>†,‡,•</sup>     | 46.3 ± 4.9 <sup>†,‡,•</sup>    | <.0001               |
| <br>CS 3600    | 15.2 ± 0.8 <sup>‡,#,§</sup>    | 23.0 ± 1.1 <sup>^,§,#</sup>     | 44.9 ± 8.9 <sup>^,§,#</sup>    | <.0001               |
| <br>Emerald    | 43.1 ± 11.5 <sup>†,‡,•,^</sup> | 49.3 ± 5.5 <sup>†,^,°</sup>     | 66.3 ± 5.6 <sup>†,^,°</sup>    | <.0001               |
| <br>DWIO       | 27.8 ± 3.2 <sup>#,•</sup>      | 49.8 ± 5.0 <sup>‡,§,*</sup>     | 92.1 ± 24.1 <sup>‡,§,°,*</sup> | <.0001               |
| <br>Omniscam | 28.4 ± 4.5 <sup>§,^</sup>      | 38.1 ± 8.8 <sup>•,#,°,*</sup>   | 70.4 ± 11.9 <sup>•,#,*,</sup>  | <.0001               |

Best Result

The same symbol after SD indicates differences in trueness between scanner pairs (Tukey-adjustment for multiple comparison). Minimum significant difference across scanners: 7.3µm, 6.6µm, 16.8µm for single crown (SC), partial prosthesis (PP) and full arch (FA), respectively. 1p-value testing the interaction between scanner and context (SC vs. PP vs. FA) from non-parametric, Kruskal-Wallis test. A p-value >0.05 indicates no difference in scanner trueness according to the context.



# Colorimetric Trueness Map Comparison

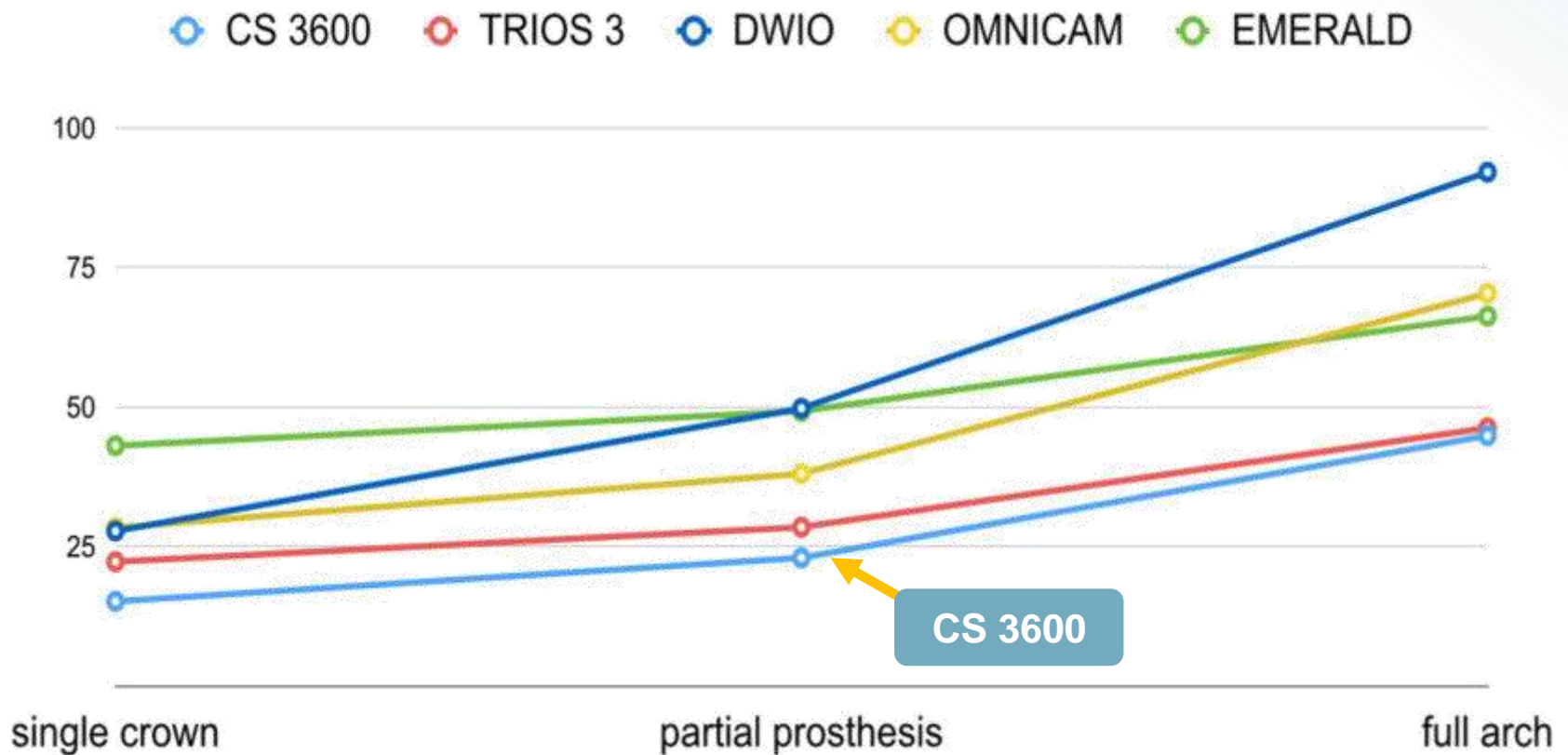


Trueness in the single crown (SC), partial prosthesis (PP) and full-arch (FA) with the 5 examined intraoral scanners (IOSs): colorimetric maps. The color maps indicated inward (blue) or outward (red) displacement between overlaid structures, whereas a minimal change was indicated by a green color. For all three models (SC, PP, FA): the color scale ranged from a maximum deviation of +100µm and -100µm, with the best result given by the deviations comprised between +30µm and -30µm (green color).








# Changes in Mean Trueness Comparison

Changes in mean trueness (standard deviation), in  $\mu\text{m}$ , for the 5 examined scanners, in the different applications (single crown, SC vs. partial prosthesis, PP vs. full-arch, FA).



# Mean Precision/Standard Deviation

| Scanner  | Single Crown<br>Mean ± SD    | Partial Prosthesis<br>Mean ± SD | Full Arch<br>Mean ± SD                       | p-value <sup>1</sup> |
|--|------------------------------|---------------------------------|--|----------------------|
| <br>Trios 3   | 15.2 ± 0.8†,‡,•              | 21.0 ± 1.9‡,•                   | 35.6 ± 3.4†,‡,•                              | <.0001               |
| <br>CS 3600   | 11.3 ± 1.1 <sup>^</sup> ,§,# | 17.0 ± 2.3 <sup>^</sup> ,§,#    | 35.7 ± 4.3 <sup>^</sup> ,§,#                 | <.0001               |
| <br>Emerald   | 32.8 ± 10.7†, <sup>^</sup>   | 29.9 ± 8.9 <sup>^</sup> ,       | 61.5 ± 11.1 <sup>^</sup> ,                   | <.0001               |
| <br>DWIO      | 27.1 ± 10.7‡,§               | 34.8 ± 10.8‡,§                  | 111.0 ± 24.8‡,§, <sup>°</sup> , <sup>¢</sup> | <.0001               |
| <br>Omnicam | 30.6 ± 3.3•,#                | 43.2 ± 9.4•,#, <sup>°</sup>     | 89.3 ± 14.0•,#, <sup>*</sup> , <sup>¢</sup>  | <.0001               |

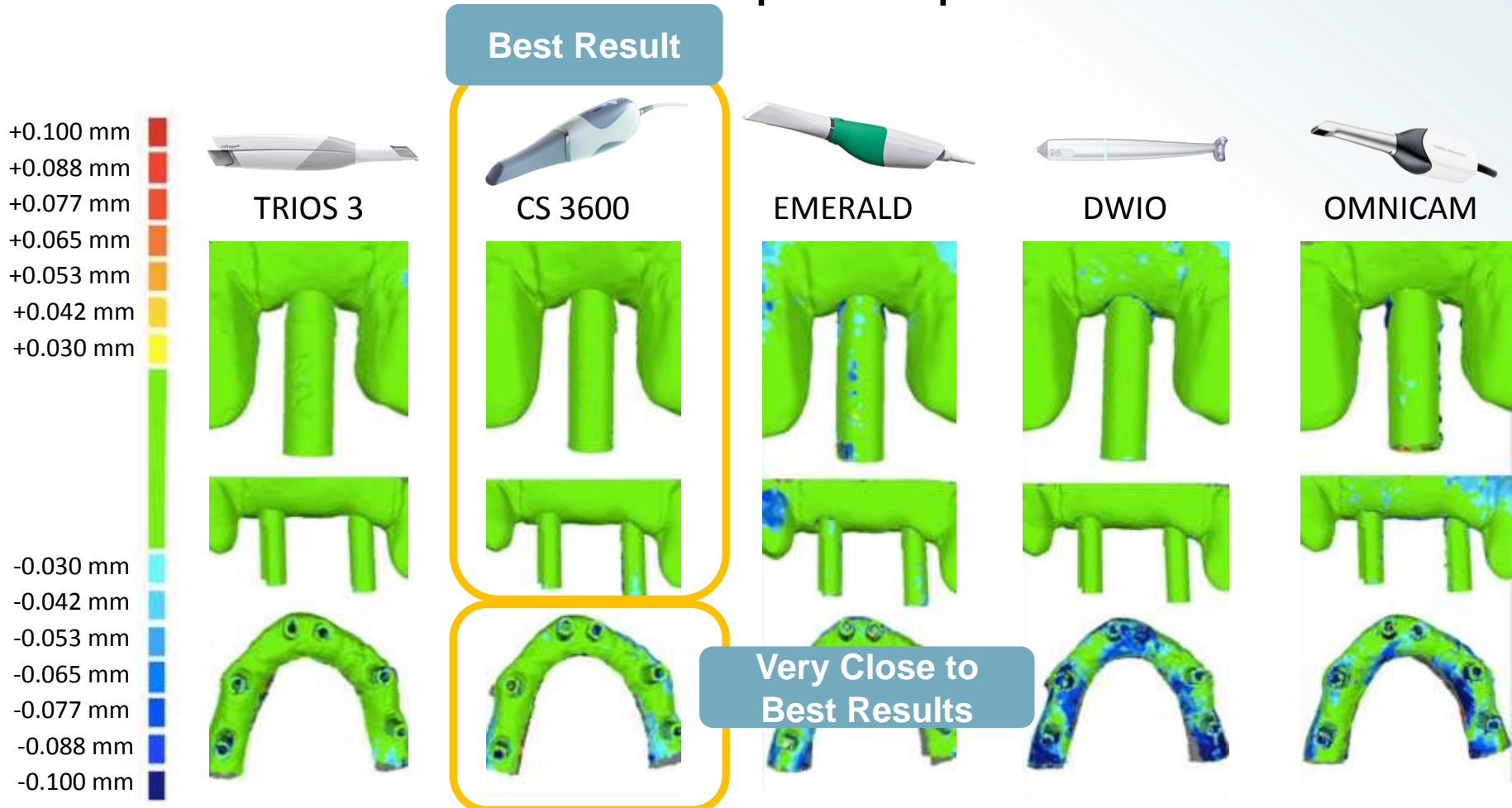
Best Result

Very closely follows best result

The same symbol after SD indicates differences in precision between scanner pairs (Tukey-adjustment for multiple comparison). Minimum significant difference across scanners: 8.8 µm, 9.8 µm, 19.4 µm for single crown (SC), partial prosthesis (PP) and full arch (FA), respectively. <sup>1</sup>p-value testing the interaction between scanner and context (SC vs. PP vs. FA) from non-parametric, Kruskal-Wallis test. A p-value > 0.05 indicates no difference in scanner precision according to the context.



# Colorimetric Precision Map Comparison

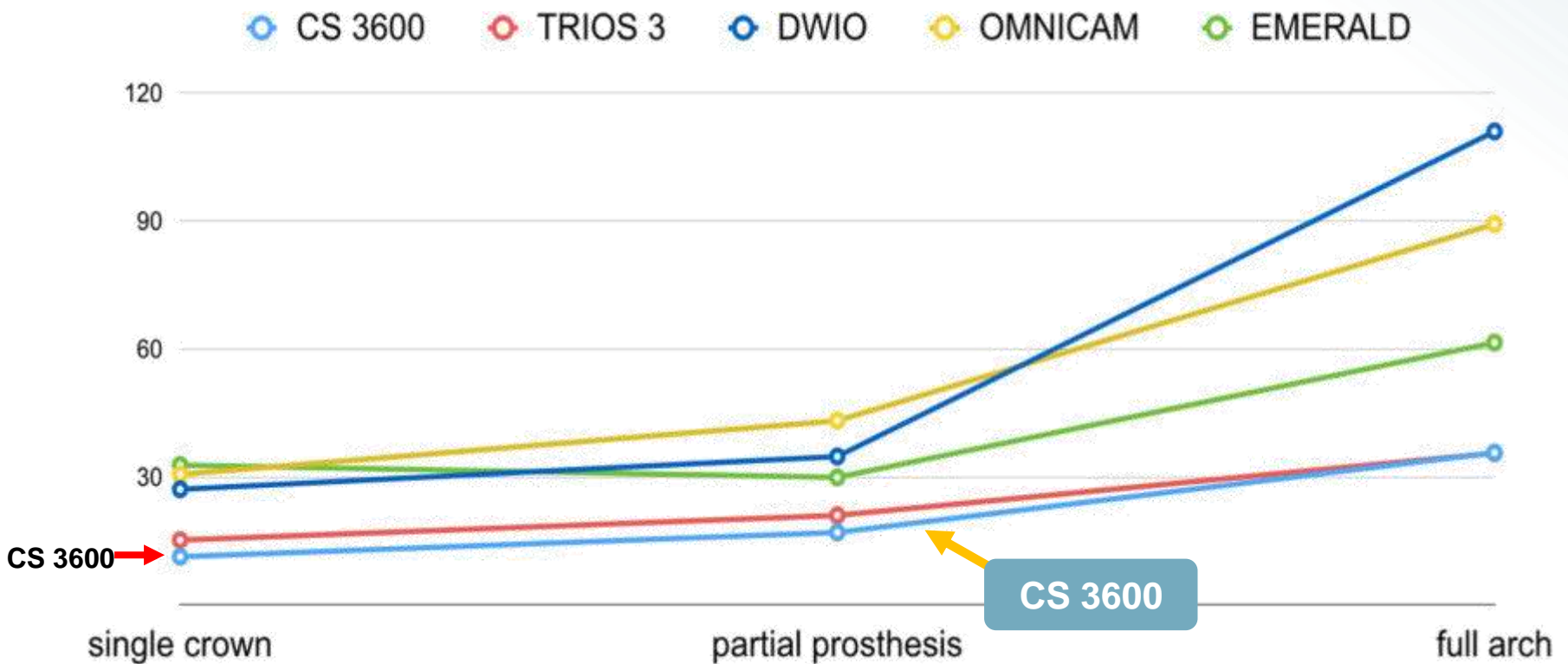


Trueness in the single crown (SC), partial prosthesis (PP) and full-arch (FA) with the 5 examined intraoral scanners (IOSs): colorimetric maps. The color maps indicated inward (blue) or outward (red) displacement between overlaid structures, whereas a minimal change was indicated by a green color. For all three models (SC, PP, FA): the color scale ranged from a maximum deviation of +100µm and -100µm, with the best result given by the deviations comprised between +30µm and -30µm (green color).



# Changes in Mean Precision Comparison

Changes in mean precision (standard deviation), in  $\mu\text{m}$ , for the 5 examined scanners, in the different applications (single crown vs. partial prosthesis vs. full-arch)

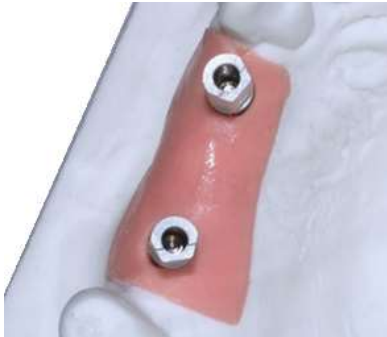


# Results Summary



## Single Crown:

CS 3600 had the best trueness ( $15.2 \pm 0.8 \mu\text{m}$ ) and the best precision ( $11.3 \pm 1.1 \mu\text{m}$ )



## Partial Prosthesis

CS 3600 had the best trueness ( $23 \pm 1.1 \mu\text{m}$ ) and the best precision ( $21 \pm 1.9 \mu\text{m}$ )



## Full Arch

CS 3600 had the best trueness ( $44.9 \pm 8.9 \mu\text{m}$ )

Trios3 had the best precision ( $35.6 \pm 3.4 \mu\text{m}$ ), followed very closely by CS 3600 ( $35.7 \pm 4.3 \mu\text{m}$ )

