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Evaluation of The Accuracy And Precision of 5 Intraoral Digital Scanners: an In-Vivo 3Dimensional Analysis

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Purpose: Many intraoral scanners that promise exceptional performance are actually in the market, but even if many data are available on in vitro tests or on plaster models, still few data are published on comparisons performed in in vivo conditions. The present study aims to compare 5 models of intraoral scanners on the market for the in vivo acquisition of full dental arches.

Aadva IOS100   Aadva IOS200   3Shape Trios 2   CS3600   Planmeca Emerald

Methods: 5 digital scanner models have been selected for the study: A) AADVA IOS100, GC Corporation, Japan; B) Emerald, Planmeca OY, Finland; C) Trios 2, 3Shape, Denmark; D) CS3600, Carestream Health Inc, USA; E) AADVA IOS200 (test version), GC Corporation, Japan. A single patient was selected as an in vivo scan model. 10 reference points were placed on the patient's teeth in upper arch. For each device, 10 scans of the arch were performed by a single operator with proven experience in using digital scanners, and respecting manufaturer's instructions (scan path and movements). Scan time and number of interruptions have been recorded. At the end of the scanning session, a PVS impression has been taken to obtain a plaster model used as "gold standard". The distances between the 10 reference points present on each 3D model were measured by 3 different operators using Final Surface™ software (version 6.8.5, Gfal, Germany). For continuous variables, the mean, standard deviation, minimum, median and maximum are calculated. For categorical variables, absolute and relative frequencies are reported. Moreover for each distance, a one way ANOVA has been implemented and Dunnett test has been applied in order to compare all the mean differences with all the scanner and the gold standard.

Fig. 1: 10 reference points place on patient's teeth in upper arch.

Results: The average scan time was 4'07 "for IOS100 (3.4 interruptions), 4'48" for IOS200 (7 interruptions), 3'08" for CS3600 (1.2 interruptions), 2'28" for Trios2 (3.1 interruptions), 2'45" for Emerald (2.3 interruptions). IOS200 test and IOS100 proved to be the fastest in preparing the model (post-processing) with 18" and 21" respectively, followed by Trios2 (24"), Emerald (47") and CS3600 (1'30 "). Compared to the "gold standard" plaster model, Emerald was statistically less accurate in 4 of the 11 measurements, followed by IOS100 (3 of 11), and Trios2 with CS3600 (1 of 11). IOS200 was the only one that showed no statistically significant differences.

Table 1: mean of the distance for the five scanners and gold standard for each distance.

		1-2	1-3	1-4	2-3	2-4	3-4	6-8	5-7	7-9	8-10	9-10
gold standard1	GYPSUM	55,086	24,319	48,881	49,239	24,513	33,069	16,512	17,178	17,895	19,316	27,054
gold standard2	IMPRESSION	54,989	23,907	48,969	49,322	24,441	33,308	16,518	17,136	18,112	19,335	26,762
average	IOS100	55,184	24,220	49,099	49,487	24,442	33,129	17,129	17,090	17,035	18,753	27,159
average	IOS200 test	54,353	24,126	47,993	49,065	24,504	32,963	16,604	16,647	17,604	19,357	27,005
average	EMERALD	54,863	24,087	48,914	48,886	24,411	32,914	17,180	16,785	16,999	18,404	27,560
average	TRIOS2	54,648	24,094	48,774	49,155	24,397	33,141	16,827	16,569	17,763	18,905	27,066
average	CS3600	55,112	23,852	49,048	49,415	24,412	33,135	16,519	22,365	17,853	661,538	27,179

		1-2	1-3	1-4	2-3	2-4	3-4	6-8	5-7	7-9	8-10	9-10
	EVALUATORS											
gold standard1	GYPSUM	55,086	24,319	48,881	49,239	24,513	33,069	16,512	17,178	17,895	19,316	27,054
Evaluator1	IOS100	55,571	24,363	49,411	49,511	24,517	33,093	17,149	17,095	16,947	18,813	27,319
	IOS200 test	54,382	24,181	48,968	49,182	24,629	33,132	16,670	16,591	17,277	19,260	26,938
	EMERALD	54,945	24,122	49,096	48,871	24,403	32,904	17,246	16,965	17,002	18,433	27,993
	TRIOS2	54,837	24,160	49,036	49,373	24,455	33,316	16,913	16,701	17,708	18,952	27,260
	CS3600	54,974	23,768	49,334	49,608	24,450	33,100	16,471	17,279	17,864	19,399	27,338
Evaluator2	IOS100	55,027	24,206	49,024	49,469	24,564	33,268	17,149	17,116	17,298	18,727	27,144
	IOS200 test	54,490	24,139	48,688	49,083	24,527	32,994	16,655	16,692	18,009	19,472	27,031
	EMERALD	54,945	24,122	49,096	48,871	24,403	32,904	17,244	16,965	17,002	18,473	27,993
	TRIOS2	54,633	24,122	48,794	49,194	24,515	33,113	16,816	16,489	17,935	19,021	26,981
	CS3600	55,251	23,802	49,024	49,431	24,555	33,025	16,604	32,599	17,921	19,359	27,164
Evaluator3	IOS100	54,954	24,092	48,862	49,482	24,244	33,025	17,059	17,059	18,423	18,718	27,015
	IOS200 test	54,186	24,058	46,324	48,932	24,356	32,764	16,485	16,658	17,436	19,337	27,046
	EMERALD	54,700	24,015	48,550	48,917	24,428	32,934	17,052	16,425	16,993	18,307	27,494
	TRIOS2	54,475	24,000	48,492	48,899	24,220	32,995	16,750	16,516	17,645	18,742	26,958
	CS3600	55,110	23,828	48,786	49,205	24,251	33,081	16,480	17,217	17,773	19,459	27,034

In RED: statistically different in respect to gold standard

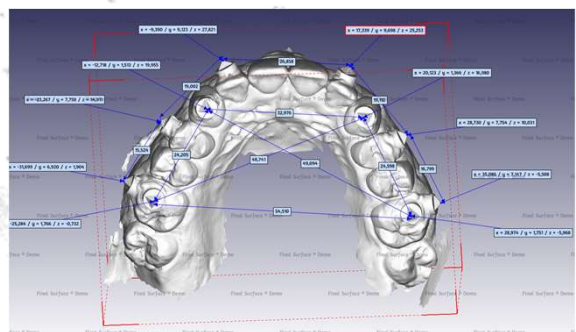**Fig 2**: distances measured using Final Surface™ software (version 6.8.5)

Table 2: comparisons between scanners and gold standard (gypsum model).

Comparisons significant at the 0.05 level are indicated by ***.			
Camera Comparison		**Difference Between Means**	**Simultaneous 95% Confidence Limits**
IOS100	- GOLD STANDARD_mod	0.05110	-0.23302 0.33522
CS3600	- GOLD STANDARD_mod	0.02180	-0.26232 0.30592
IOS200	- GOLD STANDARD_mod	0.01370	-0.27042 0.29782
Trios	- GOLD STANDARD_mod	0.00240	-0.28172 0.28652
Emerald	- GOLD STANDARD_mod	-0.03770	-0.32182 0.24642
GOLD STANDARD2_impr - GOLD STANDARD_mod		-0.07200	-0.45511 0.31111

Conclusions: All tested devices appeared to be sufficiently precise in most measurements and able to respect the tolerability currently accepted in prosthetic dentistry, equal to about 100/150 microns. Some scanners showed statistical differences in some measurements, but unexpectedly, these distortions were not detected in measurements between the most distant marks, where the longer distance between points normally causes alterations. Scanning technique and respect of manufacturer's indications still play an important role in the final image quality. Scan time doesn't seem to be related to final image quality. AADVA IOS200, CS3600 and Trios2 seem to be the most precise and reliable choices.