

COMPARATIVE ANALYSIS OF FOUR FACIAL-SCANNERS FOR CLINICAL AND RESEARCH APPLICATIONS

Grad Rareș¹, Cârstea Alexia-Ecaterina^{1*}, Vasilescu Vlad-Gabriel^{2*}, Tâncu Ana-Maria-Cristiana³, Imre Marina³, Ciocan Lucian-Toma²

¹ Student, “Carol Davila” University of Medicine and Pharmacy, 050474 Bucharest, Romania; rares.grad@stud.umfcd.ro, alexia-ecaterina.carstea2023@stud.umfcd.ro

² Discipline of Dental Prosthesis Technology, Faculty of Dentistry, “Carol Davila” University of Medicine and Pharmacy, Dionisie Lupu Street, No. 37, District 2, 020021 Bucharest, Romania; vlad.vasilescu@umfcd.ro; lucian.ciocan@umfcd.ro

³ Discipline of Prosthodontics, Faculty of Dentistry, “Carol Davila” University of Medicine and Pharmacy, 37 Dionisie Lupu Street, District 2, 020021 Bucharest, Romania; anamaria.tancu@umfcd.ro, marina.imre@umfcd.ro

Corresponding authors: Cârstea Alexia-Ecaterina email alexia-ecaterina.carstea2023@stud.umfcd.ro
Vasilescu Vlad-Gabriel email vlad.vasilescu@umfcd.ro,

ABSTRACT

Introduction This study evaluates the comparative performance of four facial-scanning systems—RAYFace, Shining 3D Einscan HX, Revopoint Inspire, and the Abound iOS application—used in clinical craniofacial imaging. As 3D scanning becomes increasingly relevant in dentistry, accurate and efficient solutions are essential for widespread implementation. **Purpose** The aim is to compare these four systems regarding geometric trueness, workflow efficiency, cost, and clinical applicability. The study seeks to determine which scanner offers the most balanced combination of precision and practicality in clinical settings. **Materials and Methods** Seven healthy volunteers underwent scans with each system under standardized lighting and posture conditions. Scan data were analyzed using surface deviation maps and landmark-based measurements, with RAYFace as the reference standard. **Results** RAYFace demonstrated the highest accuracy, while Einscan HX was the most precise among mobile systems (0.72 mm mean deviation). Revopoint and Abound exhibited greater variability and depth-bias, particularly at lateral landmarks. **Conclusions** RAYFace and Einscan HX deliver high-fidelity outputs but require substantial investment or operator training. Portable alternatives like Revopoint and Abound are more user-friendly and affordable but less reliable for high-precision tasks. Scanner selection should be guided by the intended clinical use, balancing accuracy with cost and ease of use. RAYFace remains ideal for high-precision applications, while Revopoint and Abound may suffice for preliminary use cases or educational applications.

Key words: Accuracy, Ergonomics, Efficiency, Clinical Applicability

INTRODUCTION

Three-dimensional facial-scanning technologies have witnessed rapid proliferation across diverse domains, with security applications constituting their most pervasive deployment owing to the inherent uniqueness of individual craniofacial morphologies [1-4]. The archetypal exemplar of this innovation is Apple’s TrueDepth camera system, which has fundamentally transformed mobile-device authentication by supplanting conventional alphanumeric credentials with biometric facial recognition. In this paradigm, the user’s visage functions as

an immutable cryptographic key—accessible exclusively to its rightful owner, given that no two facial architectures are congruent. Despite its pervasive integration into quotidian life, the sophisticated engineering underpinning such systems frequently eludes broader appreciation. Upon each authentication attempt, the TrueDepth apparatus acquires a high-fidelity, three-dimensional topography of the user’s face and executes a sub-second comparative analysis against the stored reference.

Analogously, the same tridimensional mapping principles are applied within

dentistry and other medical specialties [5], wherein submillimetric accuracy is imperative for diagnostic and therapeutic interventions. The exigency for surgical-grade precision necessitates instrumentation of considerable complexity and cost [6], thereby constraining current utilization to specialized rather than routine clinical environments. Nonetheless, the proliferation of manufacturers, coupled with advancements in user-interface design [7, 8] and enhancements in volumetric scan resolution [9], portends imminent mainstream adoption. Consequently, it is foreseeable that, in the near future, facial-scanning modalities will achieve routine implementation [10] in clinical practice, where the requisite capital investment is more readily justified by the imperative of diagnostic exactitude.

MATERIALS AND METHODS

In this investigation, four facial-scanning modalities—three dedicated systems and one smartphone application—were subjected to a head-to-head comparison, with devices ranked in descending order of acquisition cost. The study was approved by the Research Ethics Committee of the “Carol Davila” University of Medicine and Pharmacy, No. 13217/30.05.2025.

A cohort of seven healthy volunteers (four male, three female; age range 20–25 years) was recruited, each participant undergoing four sequential scans, one with each system, on the same day, in the same enclosed laboratory space, and under uniform ambient illumination of approximately 500 lux to eliminate shadows or uneven exposure. Subjects were seated on a fixed-base, height-adjustable chair and instructed to adopt a natural, relaxed head posture throughout each acquisition. Scanning order was randomized for each individual, and inter-scan intervals were kept under five minutes to minimize variations in facial expression or physiologic movement.

All dedicated scanners were connected to high-performance workstations equipped with multi-core processors, at least 16 GB of RAM, and professional-grade graphics cards capable of running vendor-supplied CAD–CAM software analogous to that used in intraoral imaging workflows. The smartphone

application operated exclusively on its native TrueDepth-enabled hardware and onboard software. Prior to each session, workstations and mobile devices were calibrated according to manufacturer guidelines. Scan durations, from initial device activation to completion of data capture, were recorded for each system, and user-interaction steps—such as calibration routines, menu navigation, and positioning guidance—were timed to assess workflow efficiency. Following acquisition, all volumetric datasets were exported in a common file format and evaluated for spatial resolution, trueness to reference geometries, and repeatability across duplicate captures using standardized phantom models.

Qualitative feedback regarding ergonomics, interface intuitiveness, and overall ease of use was collected via structured questionnaires administered immediately after each scanning session. This rigorous, standardized protocol ensured that observed differences in scan performance, operational ergonomics, and time efficiency were attributable solely to the intrinsic characteristics of each system.

RAYFace

The RAYFace system, manufactured by Ray (South Korea) at an acquisition cost of approximately €20 000, is the sole purpose-built, fixed-installation device evaluated in this study. As a benchtop unit resembling laboratory scanners, it necessitates placement on a stable, height-adjustable surface—preferably a dedicated table, although an adjustable-height chair may suffice to align the scanner’s bilateral arms with the subject’s facial midline irrespective of stature. Ray, a specialist in medical imaging hardware (including computed tomography and orthopantomography systems), has engineered RAYFace specifically for high-precision craniofacial mapping. During each acquisition, the subject is seated with the Frankfurt horizontal plane parallel to the floor and instructed to gaze at a distant point to standardize head posture. Real-time guidance is provided via the host computer’s display, which concurrently presents multiple camera views within color-coded frames: red indicates misalignment, while green confirms correct

positioning.

Once all camera feeds are framed in green, the operator initiates capture, which completes in under one second to produce a high-fidelity volumetric dataset. Automated post-processing by the vendor software concludes within seconds, yielding a ready-to-analyze three-dimensional facial model. The RAYFace workflow is thus distinguished by its intuitive alignment protocol, rapid acquisition time, and engaging patient experience.

Shining 3D Einscan HX

The Shining 3D Einscan HX system, acquired at an approximate cost of €14 000, is a handheld, industrial-grade optical scanner weighing 710 g and originally designed for applications such as automotive reverse engineering, video-game asset creation, and fine-arts digitization [16, 17]. For facial capture, the rapid optical-texture mode was selected to record both geometry and color texture; although this mode sacrifices some measurement accuracy compared with the laser-scan option, it offers substantially reduced acquisition time [18]. Optimal working distance is 470 mm for general objects, but for facial scanning the operator maintains a stand-off of approximately 320 mm, as indicated by the device's integrated distance-feedback system and the companion PC software, which signal too-close alignment via red illumination, optimal range via green, or excessive distance via blue [17, 19].

Subjects were seated on a fixed, upright chair with the Frankfurt horizontal plane parallel to the floor, gaze fixed on a point at eye level throughout the scan. The operator manually traversed the scanner around the subject's head to capture the full facial contour, maintaining the recommended distance and monitoring real-time feedback to ensure continuous, artifact-free data acquisition. Total scan duration averaged one minute, though this varied with operator proficiency; frequent interruptions due to distance-misalignment—particularly among less experienced users—could extend acquisition to several minutes. In addition, the scanner's bright illumination and the necessity for the subject to remain motionless posed

challenges, as patient discomfort and involuntary tracking of the moving device often introduced registration errors, necessitating re-scans. Following raw data capture, vendor software performed an automated mesh generation and alignment sequence; however, additional manual adjustments and parameter selections were required to produce the final, watertight 3D model, extending post-processing time by up to five minutes. Consequently, while the Einscan HX affords flexibility and portability, its facial-scanning workflow is markedly more complex, time-intensive, and sensitive to user technique than that of the fixed-installation RAYFace system.

Revopoint Inspire 3D Scanner

The Revopoint Inspire 3D Scanner, at an approximate acquisition cost of €500, represents the most economically accessible and physically compact device evaluated, weighing just 140 g with dimensions comparable to a modern smartphone. Originally conceived for medium-sized object digitization (minimum capture volume $50 \times 50 \times 50$ mm), its optimal working distance of 250–500 mm renders it well suited to full-face scanning. Operation proceeds via a handheld optical-structured-light modality analogous to that of the Einscan HX, yet the Revopoint mobile application—deployable on both smartphones and tablets—offers a more streamlined user interface and dedicated facial-scan mode, indicating that facial capture was an explicit design objective.

Subjects were again seated upright on a fixed chair with the Frankfurt horizontal plane parallel to the floor, maintaining gaze on a fixed eye-level target throughout the approximately 60 s acquisition. The operator circumnavigates the patient's head, tracing facial contours while the device continuously constructs the three-dimensional mesh in real time. The system's integrated illumination, although necessary for texture mapping, is less intense and more comfortable for the subject than that of the Einscan HX. Distance feedback within the app guides the operator to remain within the 250–500 mm capture range, and device freezes due to misalignment occur infrequently, resulting in more consistent scan

times across users of varying experience.

Postprocessing within the Revopoint application mirrors the Einscan workflow—automatic mesh alignment and texture projection—but benefits from simplified menus and expedited processing. However, the exported file sizes (300–400 MB) substantially exceed those generated by the other systems (20–30 MB), imposing longer CAD–CAM import times and greater storage requirements. Overall, the Revopoint Inspire affords novice clinicians superior ease of use and portability relative to the Einscan HX, yet shares similar trade-offs in scan accuracy and data management when compared to the fixed-installation RAYFace system.

Abound Application

The Abound application (formerly Metascan) is an iOS-based photogrammetric solution deployable on iPhone and iPad models released after 2015 or running iOS 15 or later, and was operated exclusively on an Apple iPhone 14 Pro for consistency. As a subscription service, its “Pro” tier is available at approximately €6.50 per month or €46 per year, entitling the user to 150 scans per month, full export in all supported formats, and 4K video export. Abound’s facial-scan workflow employs the “Photo” mode, which reconstructs three-dimensional geometry by identifying and matching common features across a series of still images. A minimum of 20 photographs—each overlapping by at least 70%—is required, with the camera positioned between a few centimeters and 500 mm from the subject, depending on the lens characteristics, to achieve optimal point-cloud density.

Opaque, matte surfaces are preferred to minimize specular reflections, and uniform, moderate ambient lighting is necessary to

avoid both harsh shadows and washed-out details. Subjects were seated on an adjustable, fixed-base chair with the Frankfurt horizontal plane parallel to the floor and instructed to maintain gaze on an eye-level target while the operator circumnavigated them, capturing discrete images rather than continuous video. Total acquisition time averaged two to three minutes—a duration shorter than that of handheld structured-light systems but longer than the sub-second capture afforded by fixed-installation devices. Image alignment and mesh generation occur automatically within the application immediately upon completion of image acquisition. However, the resulting models lack true color texture and real-scale vertex coloring, a limitation offset by the system’s low cost and universal smartphone compatibility.

Comparative Analysis of Facial Scan Data

Each facial dataset was exported in OBJ format and imported into Exocad for a comprehensive, side-by-side evaluation, providing a uniform framework for comparison across all four systems. Simple quantitative metrics such as triangle count or nominal resolution proved insufficient due to variations in scan coverage; therefore, a combined approach of surface-deviation analyses and meticulous visual inspection of fine anatomical structures was adopted. Both the color-textured meshes and their corresponding monochromatic counterparts were examined to distinguish genuine geometric fidelity from the visual realism introduced by photographic overlays illustrate the aspect of a printed paper.



Fig. 1.a) Color Scan, RAYFace



**Fig. 1.b) Color Scan, Shining 3D
EinscanHX**



**Fig. 1.c) Color Scan, Revopoint 3D
Scanner**



Fig. 1.d) Color Scan, Abound, iOS

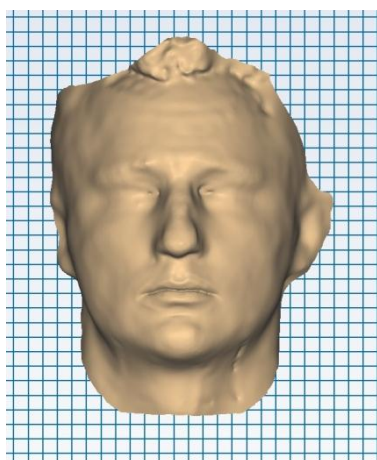


Fig. 2.a) Model Scan, RAYFace

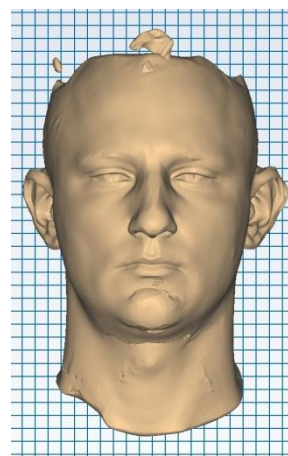


**Fig. 2.b) Model Scan, Shining 3D
EinscanHX**

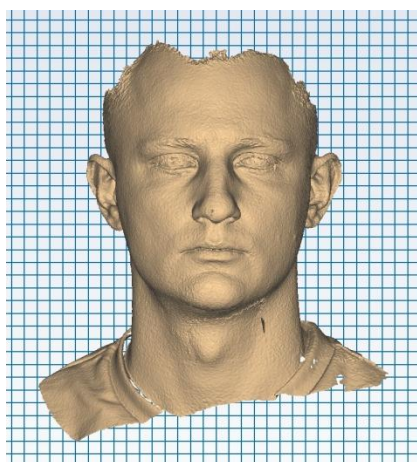


Fig. 2.c) Model Scan, Revopoint 3D Scanner

coherent light-reflection patterns and

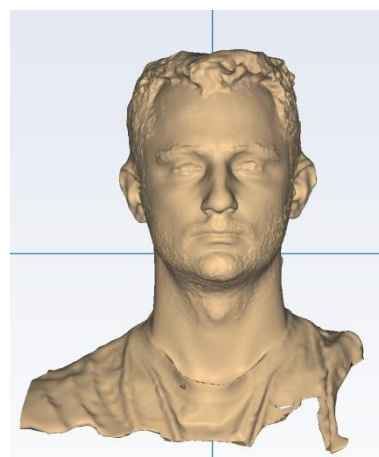


Fig. 2.d) Model Scan, Abound (iOS)

The RAYFace and Abound outputs—both employing stereophotogrammetric principles—demonstrated exceptional surface texture realism. Minute skin relief and subtle chromatic nuances were faithfully rendered by mapping high-resolution photographs onto the underlying three-dimensional scaffold. However, upon removal of these color overlays, the underlying meshes revealed a degree of surface smoothing that attenuated critical landmarks: palpebral fissures appeared softened, eyelid contours lost their sharp definition, and auricular folds exhibited reduced delineation. These observations indicate that while photographic texturing enhances perceived detail, it can also mask limitations in the raw mesh geometry. (Fig. 1, Fig. 2)

In contrast, the Shining 3D Einscan HX and Revopoint Inspire systems—both based on structured-light point-cloud acquisition followed by mesh reconstruction—produced monochromatic models whose geometry was faithfully preserved in their colorized versions. Sharp transitions at the eyelid margins, the curvature of the antihelix, and the intricate folds of the tragus were consistently captured, demonstrating true three-dimensional accuracy rather than reliance on surface imagery for detail. Although these scans lacked the photographic realism of stereophotogrammetric outputs, their textured representations nevertheless exhibited

maintained natural-looking micro-shadows, resulting in a more authentic sense of depth compared to purely overlaid color models.

A common shortcoming of all dedicated scanners was their inability to resolve individual hair strands on both the scalp and facial regions. Structured-light systems uniformly rendered hair as smooth, cap-like surfaces devoid of filament detail, and even the RAYFace device—despite partial capture of hair volume—failed to reproduce fine hair texture. By contrast, the Abound photogrammetry workflow captured the overall hair form in both color and monochrome meshes, albeit without true fiber-level texture, producing a homogeneous surface tinted by the application rather than defined by individual hair strands [20].

Consistent ambient illumination emerged as a critical factor for all modalities. Dedicated hardware allowed precise adjustment of illumination intensity to optimize contrast without provoking glare, whereas the mobile photogrammetry approach lacked integrated lighting control and depended entirely on environmental conditions. This discrepancy manifested as slight variations in brightness and hue across sequential scans, attributable to differences in camera exposure and automatic white-balance algorithms. Such variability underscores the importance of operator proficiency: hardware systems afford standardized lighting setups, while mobile photogrammetry demands

careful environmental management to minimize color inconsistencies.

Structured-light scanners deliver superior geometric fidelity at the expense of the photographic realism afforded by stereophotogrammetry, which excels in color detail but may conceal mesh deficiencies. The mobile photogrammetry solution offers unparalleled portability and captures volumetric hair form, yet sacrifices both color-texture accuracy and processing efficiency. Ultimately, the selection of an appropriate facial-scanning modality must balance the imperatives of true three-dimensional accuracy, lifelike visual representation, workflow complexity, and the practical constraints of cost, portability, and user expertise.

Objective Comparative Analysis

For objective comparison, the RAYFace scan was designated as the reference standard against which all other datasets were aligned and evaluated. This choice was based on RAYFace's dedicated craniofacial design, its high geometric precision, and its automated alignment to the natural head position (NHP). Each non-reference scan was first coarsely aligned to the RAYFace mesh by manually selecting six homologous anatomical landmarks—the bilateral endocanthia (inner canthi), bilateral alare points (nasal wings), the pronasale (nasal tip), and the subnasale (base of the columella). Following this initial proximity alignment, an automated best-fit

registration algorithm within Exocad optimized the superimposition to maximize surface congruence.

Once all models were co-registered, color-coded deviation maps were generated to visualize local depth differences across the facial surface. The chosen color scale encoded discrepancies of 0–0.5 mm in blue, 0.5–1.0 mm in green, 1.0–1.5 mm in yellow–orange, and beyond 2.0 mm in red. Fronto-medial and sagittal views of each map were inspected to identify regions of minimal deviation (predominantly blue and green) versus areas of greater mismatch (yellow, orange, or red). For example, the RAYFace versus Einscan HX overlay exhibited extensive blue and green zones around the perioral region and nasal contour, indicating deviations under 1 mm, with isolated yellow highlights along the zygomatic arch and supraorbital rim. In contrast, the RAYFace–Revopoint comparison revealed expanded yellow–orange bands around the lips and nasal base and red outliers along the lateral facial margin, signifying more pronounced geometric differences. The RAYFace–Abound overlay, though largely blue, displayed red and yellow foci at the glabellar region, left zygion, pronasale, and pogonion, reflecting the photogrammetric application's reduced accuracy at extremities. (Fig. 3, Fig. 4, Fig. 5)

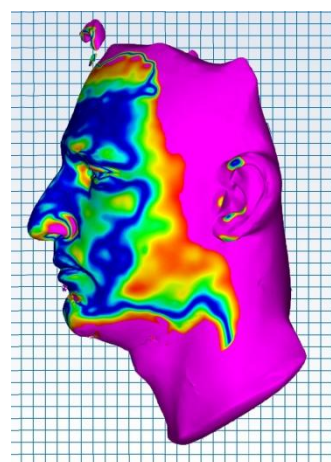
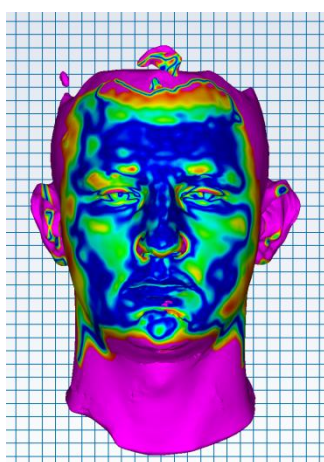


**Fig. 3 Comparison between RAYFace
vs Shinning 3D Einscan HX**



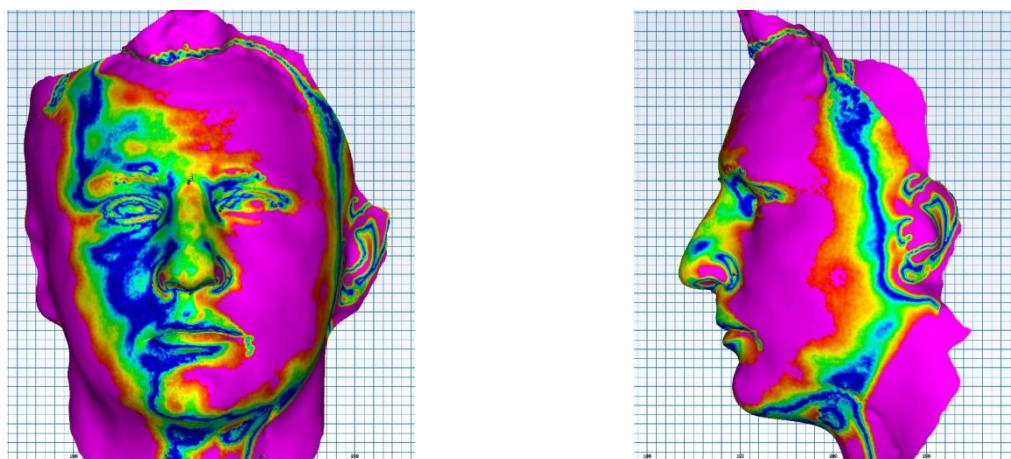


Fig. 4: Comparison between RAYFace and Revopoint 3D Scanner.

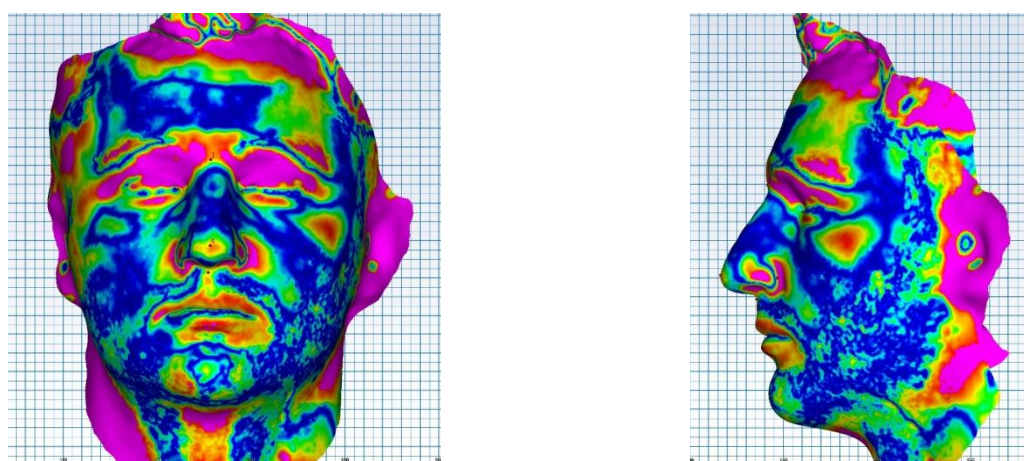


Fig. 5: Comparison RAYFace vs Abound (iOS)

To complement the surface-map analysis with precise quantitative metrics, sagittal cross-sections were extracted from each co-registered mesh at six anatomically defined points: glabella, pronasale, subnasale, pogonion, and bilateral zygions. At each location, the shortest distance between the reference and test surfaces was measured. Mean absolute deviations were then

calculated for each scanner across all six sites, yielding a concise numerical summary of geometric fidelity relative to the RAYFace gold standard. This dual approach—colorimetric mapping supplemented by point-wise deviation statistics—provides a robust and reproducible framework for objectively comparing diverse facial-scanning technologies. (Fig. 6, Fig. 7)

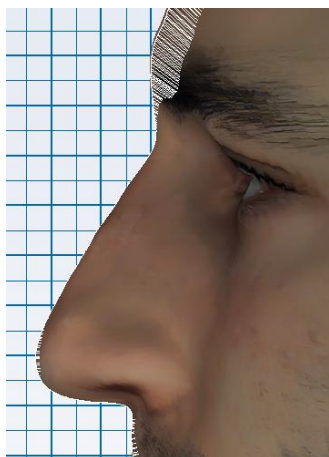


Fig. 6.a) RAYFace, sagittal section

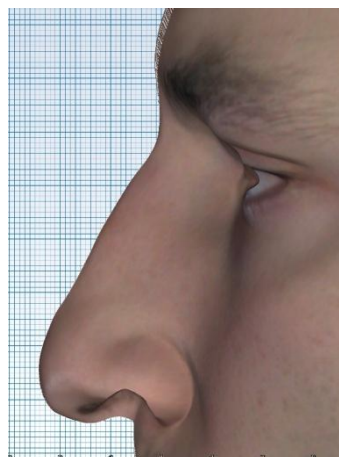


Fig. 6.b) Shinning 3D EinscanHX, sagittal section

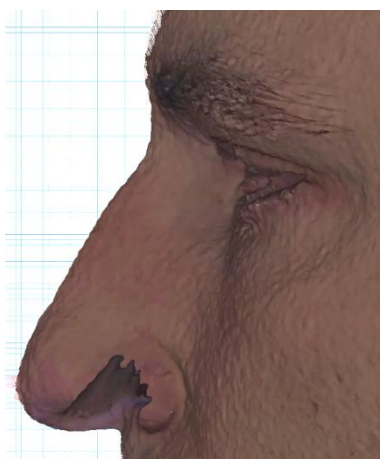


Fig. 6.c) Revopoint sagittal section

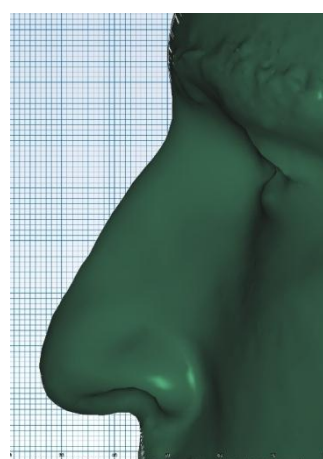


Fig. 6.d) Abound (iOS), sagittal section

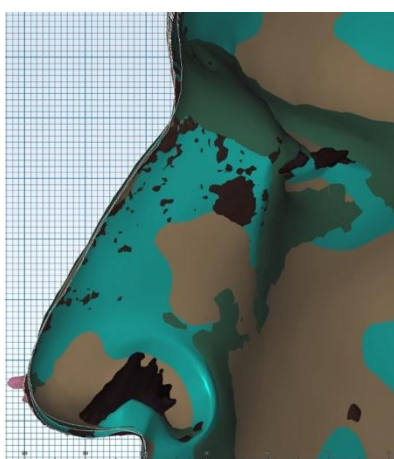


Fig. 7: Overlay of the scans in the sagittal section.

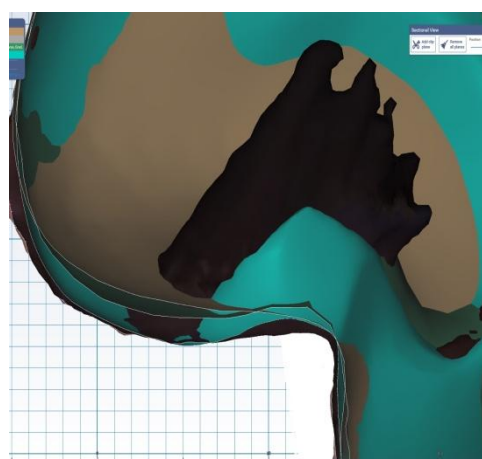


Fig. 7: Overlay of the scans in the sagittal section, magnified image at the nasal level

RESULTS AND DISCUSSIONS

Sagittal section distances between each test device and the RAYFace reference scan were measured at six anatomically defined landmarks—glabella, pronasale, subnasale, pogonion, and bilateral zygions—for all seven study participants. The raw inter-

scan discrepancies were tabulated per subject (Table 1) and subsequently averaged to yield mean absolute deviations for each device across all landmarks.

Table 1. Distances to All Anatomical Landmarks

Pacients	Facial Point - RayFace (baseline)	Distance EinScanHX (mm)	Distance Revopoint (mm)	Distance Abound (mm)
1GA	Glabella	0.35	2.03	2.93
1GA	Pronasale	0.5	1.28	1.56
1GA	Subnasale	0.94	1.06	2.8
1GA	Pogonion	1.38	1.96	4.5
2GR	Glabella	0.33	0.34	1.92
2GR	Pronasale	0.16	1.24	0.3
2GR	Subnasale	1.17	1.4	0.4
2GR	Pogonion	2.5	1.73	2
3GR	Glabella	0.37	0.76	0.9
3GR	Pronasale	0.36	0.93	0.46
3GR	Subnasale	0.8	2.54	1.88
3GR	Pogonion	0.47	1.51	0.48
4GC	Glabella	0.29	2.98	2.61
4GC	Pronasale	0.2	1.56	2.1
4GC	Subnasale	0.73	0.84	0.85
4GC	Pogonion	1.34	2.2	1.45
5RV	Glabella	0.46	0.65	1.07
5RV	Pronasale	0.59	1.26	1.18
5RV	Subnasale	0.36	0.92	1.56
5RV	Pogonion	0.11	0.91	0.26
6FG	Glabella	0.06	3.65	2.22
6FG	Pronasale	0.6	0.92	0.7
6FG	Subnasale	0.45	2.45	1
6FG	Pogonion	0.83	1.17	2.8
7PI	Glabella	0.17	1.61	2.98
7PI	Pronasale	0.47	1.38	1.54
7PI	Subnasale	1.24	1.45	2.04
7PI	Pogonion	1.4	0.61	0.83
1GA	Zygion left	0.14	1.63	1.9
1GA	Zygion right	0.76	2.3	0.53
2GR	Zygion left	1.09	1.89	1.41
2GR	Zygion right	2.35	0.98	3.15
3GR	Zygion left	0.25	4.02	0.87
3GR	Zygion right	2.06	1.54	2.22

4GC	Zygion left	0.12	1.29	0.73
4GC	Zygion right	0.81	1.27	2.65
5RV	Zygion left	0.14	0.34	4.22
5RV	Zygion right	0.88	0.77	1.02
6FG	Zygion left	1.25	1.7	0.8
6FG	Zygion right	0.95	1.31	3.1
7PI	Zygion left	0.69	2.4	1.76
7PI	Zygion right	0.17	0.66	0.18

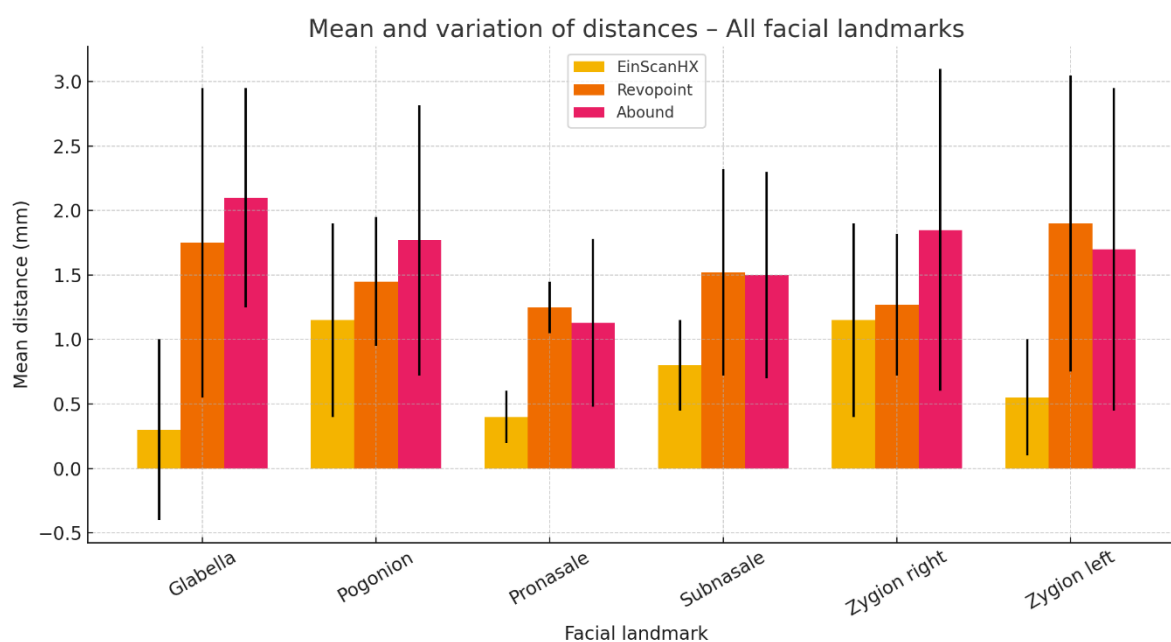


Fig. 8. Graphical representation of the mean distances and their variability

The Einscan HX consistently demonstrated the lowest mean deviation from the RAYFace standard at all six measurement sites, achieving an overall mean distance of 0.72 mm and exhibiting the smallest inter-subject variability. Both the Revopoint Inspire and the Abound iOS application produced

larger average deviations of 1.51 mm and 1.66 mm, respectively. Notably, Abound occasionally outperformed the Revopoint scanner at select landmarks (pronasale, subnasale, and left zygion), but its per-patient variability remained substantial. (Table 1, Fig. 2)

Table 2. Distances at landmarks located on the midline

Pacients	Facial Point - RayFace (baseline)	Distance EinScanHX (mm)	Distance Revopoint (mm)	Distance Abound (mm)
1GA	Glabella	0.35	2.03	2.93
1GA	Pronasale	0.5	1.28	1.56
1GA	Subnasale	0.94	1.06	2.8
2GR	Glabella	0.33	0.34	1.92

2GR	Pronasale	0.16	1.24	0.3
2GR	Subnasale	1.17	1.4	0.4
3GR	Glabella	0.37	0.76	0.9
3GR	Pronasale	0.36	0.93	0.46
3GR	Subnasale	0.8	2.54	1.88
4GC	Glabella	0.29	2.98	2.61
4GC	Pronasale	0.2	1.56	2.1
4GC	Subnasale	0.73	0.84	0.85
5RV	Glabella	0.46	0.65	1.07
5RV	Pronasale	0.59	1.26	1.18
5RV	Subnasale	0.36	0.92	1.56
6FG	Glabella	0.06	3.65	2.22
6FG	Pronasale	0.6	0.92	0.7
6FG	Subnasale	0.45	2.45	1
7PI	Glabella	0.17	1.61	2.98
7PI	Pronasale	0.47	1.38	1.54
7PI	Subnasale	1.24	1.45	2.04
1GA	Pogonion	1.38	1.96	4.5
2GR	Pogonion	2.5	1.73	2
3GR	Pogonion	0.47	1.51	0.48
4GC	Pogonion	1.34	2.2	1.45
5RV	Pogonion	0.11	0.91	0.26
6FG	Pogonion	0.83	1.17	2.8
7PI	Pogonion	1.4	0.61	0.83

To isolate midline performance, distances at paramedian landmarks (bilateral zygions) were excluded and mean deviations recalculated using only the four midline points (Table 2). Consistent with the full-landmark analysis, the Einscan HX achieved the lowest mean deviation of 0.66 mm (Fig. 9), whereas the Revopoint and Abound devices again

yielded comparable but higher means of 1.47 mm and 1.61 mm, respectively, along with greater standard deviations.

Table 3. Distances at paramedian landmarks

Pacients	Facial Point - RayFace (baseline)	Distance EinScanHX (mm)	Distance Revopoint (mm)	Distance Abound (mm)
1GA	Zygion left	0.14	1.63	1.9
1GA	Zygion right	0.76	2.3	0.53
2GR	Zygion left	1.09	1.89	1.41
2GR	Zygion right	2.35	0.98	3.15
3GR	Zygion left	0.25	4.02	0.87
3GR	Zygion right	2.06	1.54	2.22
4GC	Zygion left	0.12	1.29	0.73
4GC	Zygion right	0.81	1.27	2.65
5RV	Zygion left	0.14	0.34	4.22
5RV	Zygion right	0.88	0.77	1.02
6FG	Zygion left	1.25	1.7	0.8
6FG	Zygion right	0.95	1.31	3.1
7PI	Zygion left	0.69	2.4	1.76
7PI	Zygion right	0.17	0.66	0.18
1GA	Subnasale	0.94	1.06	2.8
2GR	Subnasale	1.17	1.4	0.4
3GR	Subnasale	0.8	2.54	1.88
4GC	Subnasale	0.73	0.84	0.85
5RV	Subnasale	0.36	0.92	1.56
6FG	Subnasale	0.45	2.45	1
7PI	Subnasale	1.24	1.45	2.04

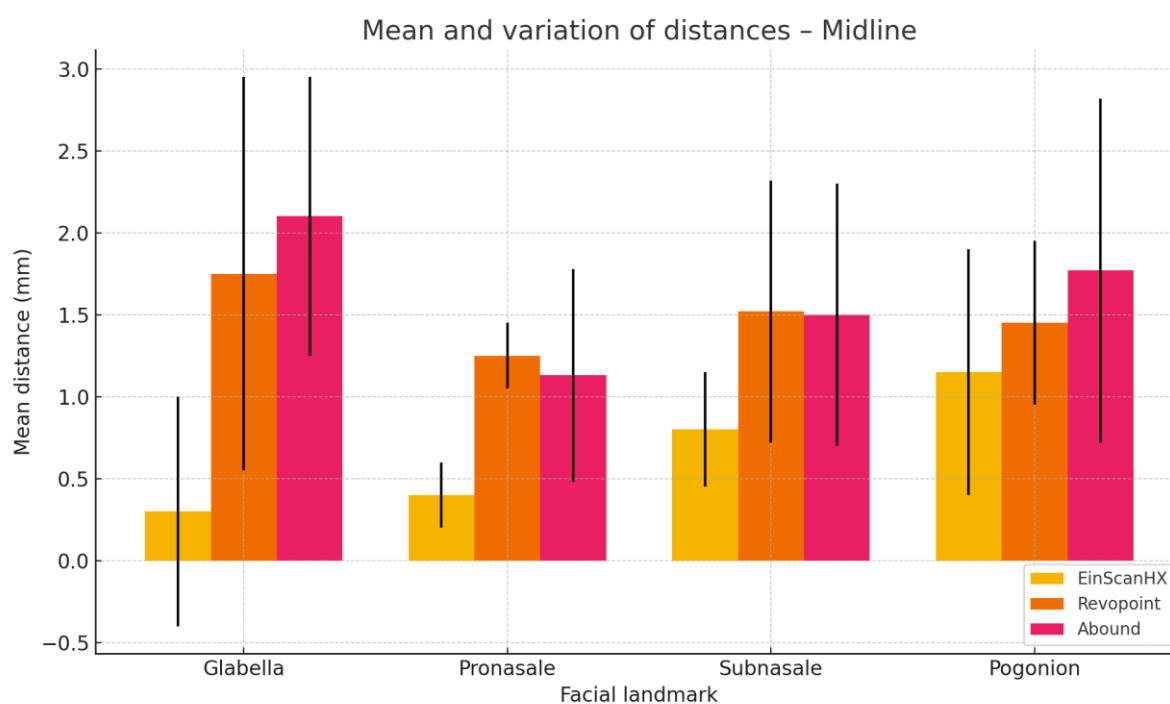


Fig. 9. Graphical representation of the averages and variation of the distances from Table 2

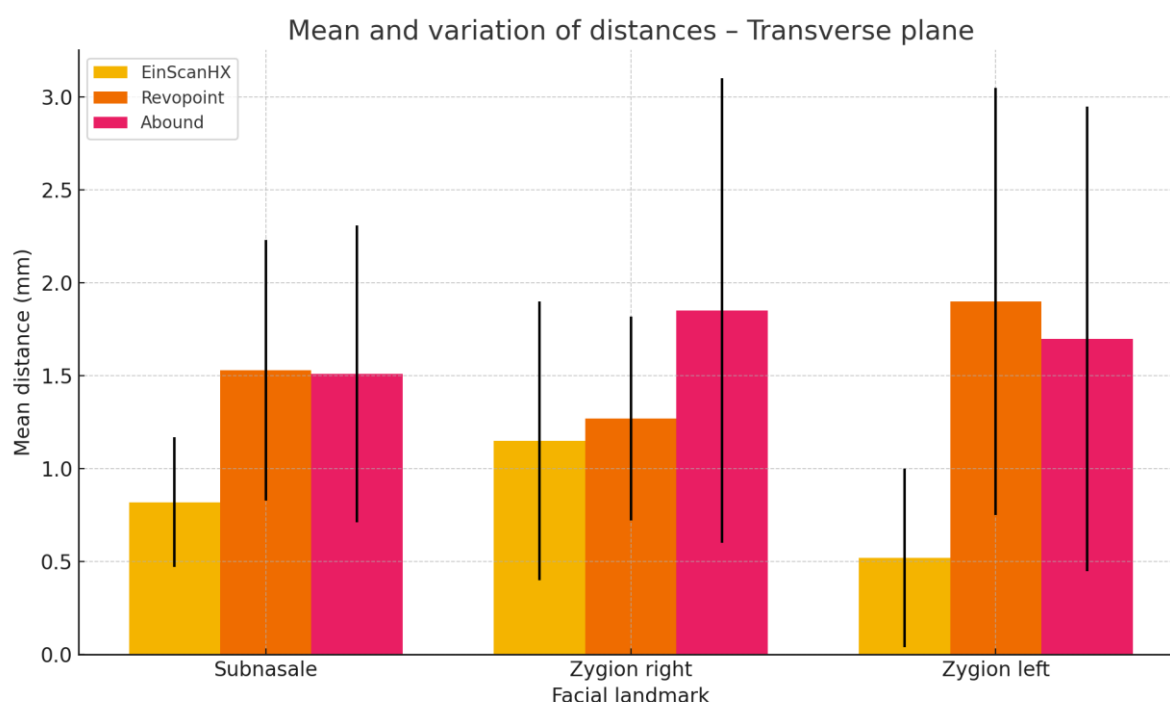


Fig. 10. Graphical representation of the averages and variation of the distances from Table 3

A focused comparison of three sagittal sections was conducted (Table 3)—subnasale plus the left and right zygions—thereby assessing each device’s performance in lateral facial regions. Across all three sections, the Einscan HX maintained the smallest mean

deviations and least variation, while the Revopoint Inspire and Abound outputs exhibited larger errors and inconsistent reproducibility, particularly for the mobile photogrammetry approach.

Table 4. Normalized distances relative to the subnasale along the midline landmarks

Pacients	Facial Points - RayFace (baseline)	Distance EinScanHX (mm)	Distance Revopoint (mm)	Distance Abound (mm)
1GA	Glabella	-0.59	0.97	0.13
1GA	Pronasale	-0.44	0.22	-1.24
1GA	Subnasale	0	0	0
1GA	Pogonion	0.44	0.9	1.7
2GR	Glabella	-0.84	-1.06	1.52
2GR	Pronasale	-1.01	-0.16	-0.1
2GR	Subnasale	0	0	0
2GR	Pogonion	1.33	0.33	1.6
3GR	Glabella	-0.43	-1.78	-0.98
3GR	Pronasale	-0.44	-1.61	-1.42

3GR	Subnasale	0	0	0
3GR	Pogonion	-0.33	-1.03	-1.4
4GC	Glabella	-0.44	2.14	1.76
4GC	Pronasale	-0.53	0.72	1.25
4GC	Subnasale	0	0	0
4GC	Pogonion	0.61	1.36	0.6
5RV	Glabella	0.1	-0.27	-0.49
5RV	Pronasale	0.23	0.34	-0.38
5RV	Subnasale	0	0	0
5RV	Pogonion	-0.25	-0.01	-1.3
6FG	Glabella	-0.39	1.2	1.22
6FG	Pronasale	0.15	-1.53	-0.3
6FG	Subnasale	0	0	0
6FG	Pogonion	0.38	-1.28	1.8
7PI	Glabella	-1.07	0.16	0.94
7PI	Pronasale	-0.77	-0.07	-0.5
7PI	Subnasale	0	0	0
7PI	Pogonion	0.16	-0.84	-1.21

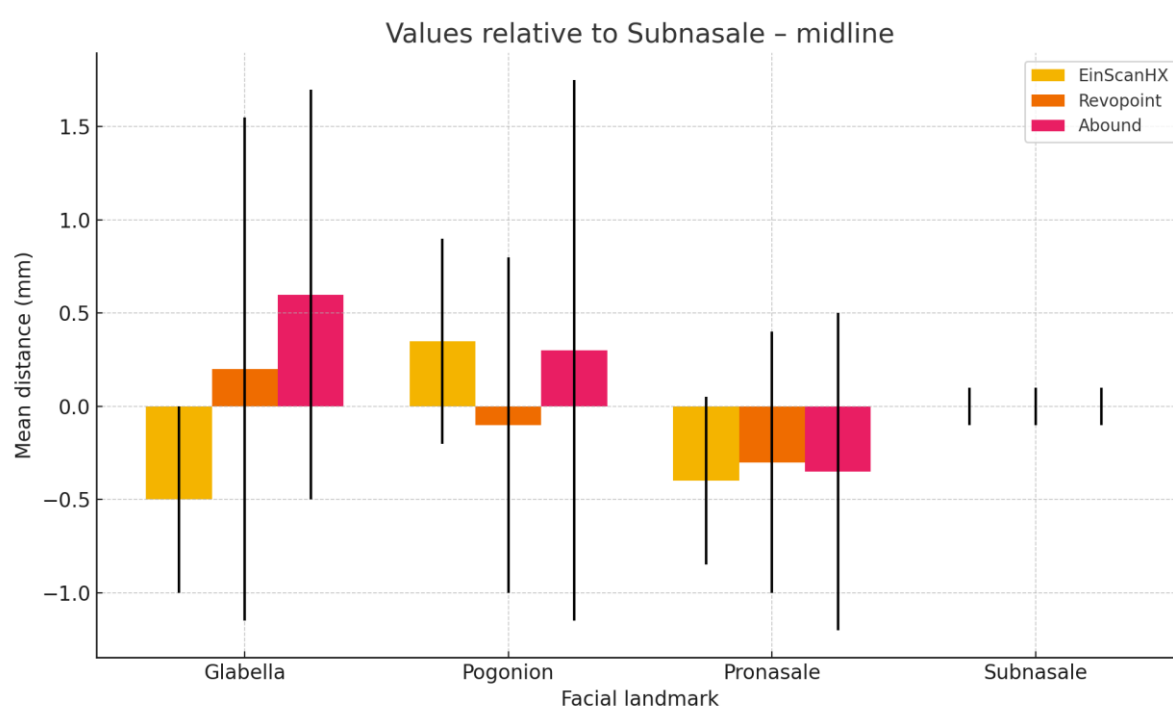


Fig. 11 Graphical representation of the averages and variation of the values from Table 4

To characterize relative depth-bias trends, normalized distances with respect to

the subnasale landmark were computed for both midline (Table 4) and paramedian (Table 5) points. In these tables, the subnasale distance is set to zero for each scan, and deviations at other landmarks reflect tendencies toward superficial or recessed positioning relative to this reference. Analysis of these normalized metrics reveals that the Einscan HX produces minimal depth-bias

across all sites, whereas both Revopoint and Abound scans display systematic shifts—often overestimating or underestimating relief in perioral and zygomatic regions—corroborating their larger absolute errors.

Table 5. Normalized distances at paramedian landmarks relative to the subnasale

Pacients	Facial Points-RayFace (baseline)	Distance EinScanHX (mm)	Distance Revopoint (mm)	Distance Abound (mm)
1GA	Zygion left	-0.8	0.57	-0.9
1GA	Zygion right	-0.18	1.24	-2.27
1GA	Subnasale	0	0	0
2GR	Zygion left	-0.08	0.49	1.01
2GR	Zygion right	1.18	-0.42	2.75
2GR	Subnasale	0	0	0
3GR	Zygion left	-0.55	1.48	-1.01
3GR	Zygion right	1.26	-1	0.34
3GR	Subnasale	0	0	0
4GC	Zygion left	-0.61	0.45	-0.12
4GC	Zygion right	0.08	0.43	1.8
4GC	Subnasale	0	0	0
5RV	Zygion left	-0.22	-0.58	2.66
5RV	Zygion right	0.52	-0.15	-0.54
5RV	Subnasale	0	0	0
6FG	Zygion left	0.8	-0.75	-0.2
6FG	Zygion right	0.5	-1.14	2.1
6FG	Subnasale	0	0	0
7PI	Zygion left	-0.55	0.95	-0.28
7PI	Zygion right	-1.07	-0.79	-1.86
7PI	Subnasale	0	0	0

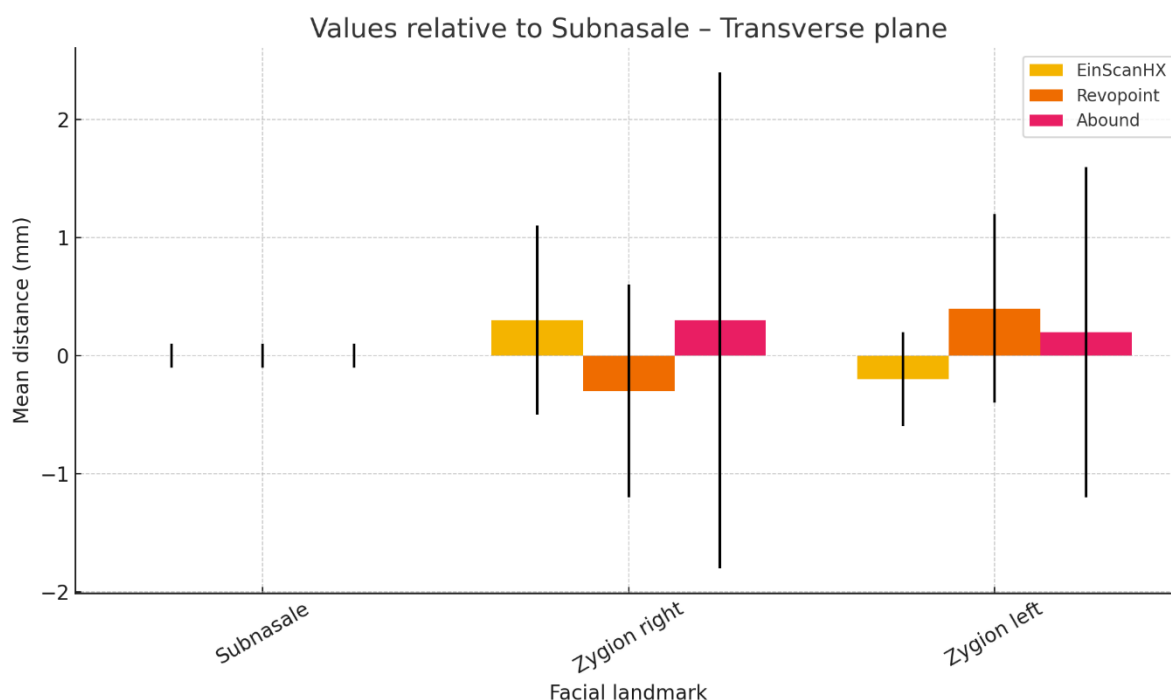


Fig. 12. Graphical representation of the averages and variation of the values from Table 5

Collectively, these quantitative findings corroborate the structured-light Einscan HX as the most geometrically faithful system relative to the RAYFace gold standard, while the Revopoint Inspire and Abound applications exhibit similar, yet less precise, performance profiles with greater inter-scan variability.

The Einscan HX demonstrates a consistent depth-bias pattern along the midline: superior landmarks (glabella and pronasale) are generally positioned deeper than the subnasale reference (negative normalized values), whereas the pogonion tends to be represented more superficially (positive normalized values), albeit with occasional scans exhibiting a deeper pogonion depiction. (Fig. 12) Conversely, there is no clear lateral bias showed for the Einscan HX at paramedian sites, as the right zygion displays positive mean values (superficial positioning) and the left zygion shows negative means (deep positioning). (Fig. 12)

For both the Revopoint and Abound systems, midline variability is markedly greater than for the Einscan HX (Fig. 11). Their mean normalized values indicate superficial placement of the glabella and

deeper representation of the pronasale relative to the subnasale reference. At the pogonion, however, the Revopoint exhibits a slight depth-bias toward deeper positioning, whereas Abound shows a tendency toward superficial displacement.

At the paramedian points, the Revopoint again lacks a consistent laterality pattern, with negative mean values at the right zygion and positive values at the left. In contrast, the Abound application yields positive mean normalized distances at both zygion landmarks (Fig. 12), indicating a systematic trend toward superficial representation of lateral facial contours relative to the subnasale.

Discussions

The quantitative analyses conducted in this study have provided an objective framework for assessing the geometric accuracy and precision of three handheld or mobile facial-scanning systems—Shining 3D Einscan HX, Revopoint Inspire 3D Scanner, and the Abound iOS application—relative to the RAYFace benchtop unit, which served as the reference standard due to its dedicated

craniofacial design, high trueness, and automated natural head position alignment [21, 22]. Across all six anthropometric landmarks and seven subjects [23], the Einscan HX demonstrated superior accuracy, with a mean absolute deviation of 0.72 mm and the smallest inter-subject variability (Table 1, Fig. 8). These findings corroborate the structured-light methodology's capacity for faithful three-dimensional capture when compared to stereophotogrammetric and photogrammetric alternatives.

By contrast, both the Revopoint Inspire and Abound systems exhibited larger mean deviations of 1.51 mm and 1.66 mm, respectively, alongside broader ranges of error. Although Abound marginally outperformed the Revopoint scanner at certain midline landmarks—namely pronasale, subnasale, and left zygion—its overall variability remained high. When midline points alone were considered (Table 2, Fig. 9), the Einscan HX again achieved the lowest mean error (0.66 mm), while the Revopoint and Abound devices yielded similar yet inferior performance (1.47 mm versus 1.61 mm). The paramedian analysis (Table 3) further confirmed the Einscan HX's consistent fidelity across lateral facial regions [20].

Normalizing distances to the subnasale reference (Tables 4 and 5; Fig. 11, 12) revealed systematic depth-bias tendencies: the Einscan HX tended to position superior landmarks (glabella and pronasale) slightly deeper (negative values) and the pogonion more superficially (positive values), indicating minimal bias and high repeatability. In contrast, Revopoint and Abound scans exhibited pronounced variability in both magnitude and direction of depth bias, reflecting their greater sensitivity to operator technique and environmental conditions. Notably, Abound displayed a consistent superficial shift at paramedian zygion points, suggesting a proclivity for under-representing lateral facial relief.

While geometric trueness and precision are paramount in applications such as virtual treatment planning and CAD–CAM integration [23], practical considerations also influence device selection. In this regard, the RAYFace unit remains the most intuitive and

patient-friendly option: its sub-second acquisition, automated alignment guidance, and minimal illumination discomfort yield high patient acceptance. However, its high acquisition cost and fixed installation limit its accessibility for routine clinical use. Conversely, the Einscan HX offers performance comparable to RAYFace in many respects but demands extensive operator training, suffers from occasional acquisition freezes, and carries a price point near that of the RAYFace, reducing its appeal for facial-scan-specific workflows.

The Revopoint Inspire emerges as a balanced alternative for clinicians seeking portability and cost savings without wholly sacrificing accuracy. Its dedicated facial-scan mode, lightweight handheld form factor, and simplified user interface mitigate many practical barriers, although its susceptibility to ambient light variation and operator-induced artifacts imposes caution [24]. Finally, the Abound mobile application—while the most accessible and patient-comfortable—lacks color-textured exports at true scale, complicating integration with intraoral models and CBCT datasets. Nevertheless, its performance approaches that of the Revopoint system, and with anticipated software enhancements, it may represent a disruptive, cost-effective solution for future digital-dentistry workflows [25].

In addition to quantitative discrepancies, the comparative analysis highlighted several operational distinctions that influence the practical deployment of these facial-scanning technologies in clinical settings [25]. While the Einscan HX consistently outperformed the other mobile systems in terms of geometric fidelity, its performance was also marked by a need for operator expertise. The structured-light modality, though inherently more stable, requires precise control of scanner-to-face distance, angulation, and movement velocity. These procedural nuances may limit its utility in high-throughput environments or among users without formal training, where reproducibility becomes more variable.

The Revopoint Inspire, although exhibiting lower trueness, offers a more accessible interface and a more forgiving

acquisition process, particularly when scanning under non-ideal spatial constraints. However, it showed increased susceptibility to external lighting conditions, with notable artifacts appearing under direct ambient illumination or in the presence of reflective skin surfaces. This variability was especially evident in the lateral regions, such as the zygomatic arches and mandibular borders, where mesh distortion and incomplete surface data were recurrent.

The Abound application, relying on a monocular photogrammetric approach embedded in consumer-grade mobile hardware, demonstrated considerable variability both within and across subjects. Although it achieved reasonably accurate midline measurements in static conditions, the device's performance was less consistent in lateral and inferior facial regions. One contributing factor may be its reliance on video-based frame stitching, which introduces compounded error if subject movement or facial expression subtly shifts during acquisition. This aspect, while not systematically quantified in the present study, was noted qualitatively across multiple trials and may be especially relevant when assessing dynamic patient populations such as pediatric or geriatric cohorts.

From a technical standpoint, the absence of real-time feedback in the Abound interface precludes immediate verification of scan completeness or mesh integrity, often necessitating multiple acquisitions to ensure diagnostic-quality results. Moreover, post-processing requirements for Abound were non-negligible, as exported meshes frequently lacked uniform scale and required manual cropping, mesh cleaning, or spatial realignment prior to integration into diagnostic or manufacturing workflows [23, 24]. By contrast, both the Einscan HX and RAYFace units produced more structured, topologically coherent outputs that facilitated immediate use in digital planning environments.

A further consideration involves the integration of facial data with intraoral scans and cone-beam computed tomography (CBCT) datasets. Only the Einscan HX and RAYFace systems preserved sufficient landmark consistency and global scale to

permit reliable multimodal alignment using standard software protocols. In contrast, neither the Revopoint nor Abound scans consistently maintained the spatial accuracy required for seamless superimposition without auxiliary calibration procedures. This constraint may present challenges in workflows requiring high-precision correspondence between extraoral and intraoral anatomical regions, such as orthognathic simulation, prosthetic rehabilitation, or temporomandibular joint assessment [25].

Conclusions

1. Facial scanning represents a rapidly emerging frontier in digital dentistry and craniofacial diagnostics. This comparative evaluation underscores the distinct strengths and limitations of four scanning platforms—RAYFace, Shining 3D Einscan HX, Revopoint Inspire, and the Abound iOS application.
2. Inspire 3D Scanner, and the Abound iOS application—demonstrates that each platform occupies a distinct niche defined by its balance of geometric fidelity, workflow complexity, patient comfort, and cost. The fixed-installation RAYFace device, with its automated alignment to natural head position, sub-second acquisition, and mean deviations consistently below 0.5 mm, delivers the highest trueness and precision among the systems tested. Its intuitive interface and minimal illumination discomfort further ensure reproducible, error-free scans, thereby justifying its higher capital investment for practices prioritizing diagnostic exactitude and seamless integration with CAD–CAM and CBCT datasets. Although the handheld Einscan HX achieves commendable accuracy (mean deviation 0.72 mm), its steep learning curve, susceptibility to acquisition interruptions, and purchase price near that of RAYFace render it less practical for routine clinical workflows. Nevertheless, its portability and structured-light technology make it a viable alternative for clinics prioritizing flexibility without fully sacrificing

accuracy.

3. In contrast, the Revopoint Inspire (mean deviation 1.51 mm) and the Abound photogrammetry app (mean deviation 1.66 mm) lower the barrier to facial scanning through portable, cost-effective designs—approximately €500 and €46 per year, respectively—and user-friendly software, yet both exhibit greater inter-scan variability and inconsistent depth-bias patterns that currently preclude their use in high-precision applications. Notwithstanding these limitations, the Revopoint's dedicated facial-scan mode and the Abound app's universal smartphone compatibility make them compelling tools for preliminary aesthetic simulation, patient education, preliminary diagnostics and educational purposes, with future software refinements likely to narrow the accuracy gap especially in academic or resource-limited settings. Notably, Abound's reliance on environmental lighting and lack of real-time mesh feedback may reduce reliability in non-controlled environments.
4. Ultimately, scanner selection should align with the intended clinical or educational application. High-fidelity systems such as RAYFace and Einscan HX are indispensable in workflows

demanding submillimetric precision, while other alternatives like Revopoint and mobile-friendly solutions like Abound may serve as complementary tools where usability, affordability, and portability take precedence. Continued software optimization, enhanced depth-capture algorithms, and improved alignment protocols will be critical in narrowing the performance gap between professional-grade and consumer-level facial-scanning solutions.

Acknowledgment: All authors acknowledge the support of Interdisciplinary Center of Research and Development in Stomatology, Digital Techniques in Dentistry Laboratory, from U.M.F. “Carol Davila” Bucharest.

REFERENCES

1. Kühlman, D.C., et al., Accuracy (trueness and precision) of four tablet-based applications for three-dimensional facial scanning: An in-vitro study. *J Dent*, 2023. 135: p. 104533.
2. Antonacci, D., et al., Facial scanning technologies in the era of digital workflow: A systematic review and network meta-analysis. *J Prosthodont Res*, 2023. 67(3): p. 321-336.
3. Gašparović, B., et al., Comparing Direct Measurements and Three-Dimensional (3D) Scans for Evaluating Facial Soft Tissue. *Sensors (Basel)*, 2023. 23(5).
4. Revilla-León, M., et al., Facial scanning accuracy depending on the alignment algorithm and digitized surface area location: An in vitro study. *J Dent*, 2021. 110: p. 103680.
5. Cauti, F.M., et al., Analysis of electrogram peak frequency during ventricular tachycardia ablation: Insights into human tridimensional ventricular tachycardia circuits. *Heart Rhythm*, 2025. 22(1): p. 128-134.

6. Regierer, B., et al., Future of medicine: models in predictive diagnostics and personalized medicine. *Adv Biochem Eng Biotechnol*, 2013. 133: p. 15-33.
7. Serban, A., et al., User Interface Design in Medical Distributed Web Applications. *Stud Health Technol Inform*, 2016. 223: p. 223-9.
8. Richert, R., et al., Intraoral Scanner Technologies: A Review to Make a Successful Impression. *J Healthc Eng*, 2017. 2017: p. 8427595.
9. Patel, N.A. and B.J. Ferguson, Odontogenic sinusitis: an ancient but under-appreciated cause of maxillary sinusitis. *Curr Opin Otolaryngol Head Neck Surg*, 2012. 20(1): p. 24-8.
10. Barone, S., et al., Accuracy Assessment of EM3D App-Based 3D Facial Scanning Compared to Cone Beam Computed Tomography. *Dent J (Basel)*, 2024. 12(11).
11. Listl, S. and R. Weyant, For careful consideration: the reporting of health economic evaluations in dentistry. *J Public Health Dent*, 2019. 79(4): p. 273-274.
12. Barootchi, S., et al., Alveolar ridge preservation: Complications and cost-effectiveness. *Periodontol 2000*, 2023. 92(1): p. 235-262.
13. Rabbani, N., et al., Applications of machine learning in routine laboratory medicine: Current state and future directions. *Clin Biochem*, 2022. 103: p. 1-7.
14. Bragança, G.F., et al., Effects of Charcoal Toothpaste on the Surface Roughness, Color Stability, and Marginal Staining of Resin Composites. *Oper Dent*, 2022. 47(2): p. 214-224.
15. Wang, J., et al., Recent Advances in Digital Technology in Implant Dentistry. *J Dent Res*, 2024. 103(8): p. 787-799.
16. Amornvit, P. and S. Sanohkan, The Accuracy of Digital Face Scans Obtained from 3D Scanners: An In Vitro Study. *Int J Environ Res Public Health*, 2019. 16(24).
17. Cutti, A.G., et al., Accuracy, Repeatability, and Reproducibility of a Hand-Held Structured-Light 3D Scanner across Multi-Site Settings in Lower Limb Prosthetics. *Sensors (Basel)*, 2024. 24(7).
18. Wang, C., et al., Trueness of One Stationary and Two Mobile Systems for Three-Dimensional Facial Scanning. *Int J Prosthodont*, 2022. 35(3): p. 350-356.
19. Thongma-Eng, P., et al., Effect of Ambient Lights on the Accuracy of a 3-Dimensional Optical Scanner for Face Scans: An In Vitro Study. *J Healthc Eng*, 2022. 2022: p. 2637078.
20. Böhringer, S. and M.A. de Jong, Quantification of Facial Traits. *Front Genet*, 2019. 10: p. 397.
21. Seifert, L.B., et al., Comparative Accuracy of Stationary and Smartphone-Based Photogrammetry in Oral and Maxillofacial Surgery: A Clinical Study. *J Clin Med*, 2024. 13(22).
22. Jindanil, T., et al., Smartphone applications for facial scanning: A technical and scoping review. *Orthod Craniofac Res*, 2024. 27 Suppl 2(Suppl 2): p. 65-87.
23. Zahedi, F.D., et al., Radiological anatomical variations of the lateral nasal wall and anterior skull base amongst different populations: A systematic review and meta-analysis. *Clin Otolaryngol*, 2023. 48(2): p. 271-285.
24. de Maio, M., et al., Multi-Dimensional Aesthetic Scan Assessment (MD ASA™): Initial experience with a novel consultation, facial assessment, and treatment planning tool. *J Cosmet Dermatol*, 2021. 20(7): p. 2069-2082.
25. Gehrke, P., et al., A systematic review of factors impacting intraoral scanning accuracy in implant dentistry with emphasis on scan bodies. *Int J Implant Dent*, 2024. 10(1): p. 20.