Facial defects contain complex anatomical structures, which makes taking facial impressions for prosthetic rehabilitation challenging when conventional methods are employed. Some challenges are related to the physical properties of the impression material, how the material is manipulated, and the required setting times. A common concern is the deformation of facial tissues due to the weight of the impression material causing distortion in the resultant facial cast.

Since digital impression techniques do not require direct application of materials, the use of noncontact digitizers in facial defect patients may offer a solution to this historical clinical problem. However, noncontact digitization techniques must demonstrate accurate reproduction of the obtained shape with reasonable acquisition time. Simplicity of use and cost of equipment are also important factors when employing technology in a clinical setting. Although most of the available noncontact digitizers offer good accuracy with relatively short acquisition time, many are expensive and often complex to use.

An alternative to expensive noncontact digitizing systems is a smartphone device with free software that can generate three-dimensional (3D) models from two-dimensional (2D) photos. In maxillofacial prosthetics, Salazar-Gamarra et al. have used monoscopic photogrammetry with a mobile device and free software to capture digital facial impressions of patients with maxillofacial defects. They concluded that it is possible to generate 3D models of digital facial impressions obtained with a smartphone as an alternative to conventional impression techniques.

**Purpose:** To evaluate the accuracy of a smartphone application as a low-cost approach for digitizing a facial defect for 3D modeling. **Materials and Methods:** A stone model of a facial defect was scanned using industrial computed tomography (reference scan) and was also scanned five times using a commercial laser scanner. A series of 24 sequenced digital photographs was taken five times by smartphone at two elevations. These images were uploaded and processed by a cloud-based server to create virtual 3D models. The 3D datasets were geometrically evaluated and compared to the reference data using 3D evaluation software. Mann-Whitney U test was used for statistical analysis, and the significance was set at P < .05. **Results:** The overall mean 3D deviation ± standard deviation for the smartphone dataset was 604.9 ± 123.5 µm compared to 67.5 ± 0.49 µm for the laser scanner. There was a significant difference in the accuracy between the commercial laser scanner and the smartphone application (P = .009). **Conclusion:** The results showed that within the limits of this study and in reference to standard computed tomography imaging, data acquisition with a smartphone for 3D modeling is not as accurate as commercially available laser scanning.

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the use of a mobile device; however, they suggested that further studies are needed to evaluate the quality indices of these models, including accuracy. Therefore, the purpose of this in vitro study was to evaluate the accuracy of a smartphone application as a low-cost approach to digitizing and 3D modeling facial defects.

**MATERIALS AND METHODS**

A flowchart outlining the data acquisition and analysis process is shown in Fig 1.

A stone facial model of a patient with a maxillary-orbital defect was digitized using computed tomography (CT) as a reference scan (TOSCANER-30000µCM, Toshiba IT & Control Systems). The stone model was then scanned five times using laser-beam light-sectioning technology (Vivid 910 scanner, Konica Minolta Sensing). For smartphone face digitizing, 123D Catch, a free photogrammetry application (Autodesk), was used on an iPhone 6S (Apple). A total of 24 two-dimensional sequenced photographs were captured by the smartphone at two elevations (6 superior and 18 horizontal). After confirming the quality of the data, the images were uploaded and processed using 123D Catch. This process was repeated five times. Five stereolithography (STL) files were created and downloaded from the 123D Catch website. All STL models were edited with Autodesk Meshmixer software (Autodesk). Editing included re-scaling models based on a reference distance that had been physically registered on the stone model and deleting extraneous data beyond the face. The 3D datasets were geometrically evaluated and compared to the reference data using 3D evaluation software (GOM Inspect, GOM). The software calculated the total differences in absolute 3D deviations using the root mean square, which represents the approximate distance between the superimposed reference scan and the test scan. A value of 0 indicates perfect accuracy, with either increasing or decreasing values indicating inaccuracy. Mann-Whitney U test was used for statistical analysis, and significance was set at $P < .05$.

**RESULTS**

The entire surface of the facial defect model was successfully digitized, modeled as 3D data, and geometrically evaluated. The raw data for summary statistics for the scan accuracy are presented in Table 1. The overall mean 3D deviation ± standard deviation for the smartphone dataset was 604.9 ±123.5 µm compared to 67.5 ± 0.49 µm for the Vivid 910 scanner. There was a statistically significant difference in the accuracy between the 3D digital models produced by the smartphone application and the laser scanner ($P = .009$).

**DISCUSSION**

Accurate 3D digitization of complex facial defects is essential to achieve a properly fitting restoration. Photogrammetry systems in general have limited accuracy in the depth measurement coordinate (z), and facial defects require accurate depth digitization. Therefore, a CT scanner and laser scanner, both known to be highly accurate, were used in this study as the reference and comparative scans, respectively. The results of this study revealed that the smartphone application showed more inaccuracy in the defect area representing the depth of the defect. The commercial laser scanner showed more
accuracy, mainly due to the use of laser-beam light-sectioning technology rather than photogrammetry.

Operator error may have contributed to the poorer accuracy with photogrammetry, given that 24 photographs were independently captured compared to the single-pass capture of the laser scanner. Additionally, to create the 3D model with photogrammetry, multiple overlapping images are processed, requiring additional computing time and increasing the potential for error. The manual re-scaling of the 123D Catch STL files based on a physically defined distance on the facial cast also introduces potential error. Additionally, a clinical concern always exists when uploading sensitive patient data to a cloud-based server.

Differences in the accuracy demonstrated in this study may be explained by the inherent technological differences of these two respective data acquisition methods. Smartphone data capture and photogrammetry require multiple steps and processes to produce the virtual 3D model, while the laser-scanning technology produces an STL file in a single static pass without added computing processes. Given the inherent differences of these respective technologies, it is essential that the user consider the clinical utility of these technologies and carefully evaluate the cost-benefit ratio and accessibility of each while acknowledging their relative accuracies. Appropriate selection of 3D technologies based on clinical needs and treatment goals must be considered carefully by the clinician. Limited accessibility to expensive 3D acquisition systems is a motivation to consider the clinical applicability of less expensive systems. The limitation must be acknowledged that, despite simulating the geometry of a real complex maxillofacial defect, the stone model did not represent an actual clinical environment in regard to various facial tissues, facial hair, patient movement, and humidity around the face. Further in vivo studies should be performed to determine whether these different variables affect accuracy.

CONCLUSIONS

Although smartphone application offers a feasible low-cost alternative for the digitizing and 3D modeling of facial defects, the results reveal that the accuracy of smartphone data capture does not compare to more expensive laser-scanning devices and therefore warrants careful selection of its application for clinical use.

ACKNOWLEDGMENTS

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REFERENCES


Table 1 Raw Data Used for Statistical Analyses on Accuracy of 3D Scanners (μm)

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<th>Mean</th>
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<th>Standard</th>
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<td>0.49</td>
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</table>

Literature Abstract

**Minimally Invasive Treatment of an Adult with Severe Pseudo Class III Malocclusion**

Pseudo-Class III malocclusion is reverse anterior occlusion or anterior crossbite with the first molars and canines in a Class I relationship. It is very important to diagnose pseudo-Class III from true skeletal Class III malocclusion. The combination of anterior displacement of the mandible, tooth wear, and loss of occlusal vertical dimension (OVD) in adults may result in an anterior crossbite. The key factor in the diagnosis of this malocclusion is an interdisciplinary approach with an orthodontist. Cephalometric images are essential for diagnosis of pseudo-Class III malocclusion. Most relevant publications on correcting this condition have recommended either full-coverage restorations or extraction and placement of implants to correct this malocclusion. Advances in materials and technology may help dental practitioners restore tooth wear and OVD with a conservative approach without removing more tooth structures. This clinical report shows the treatment of pseudo-Class III malocclusion with minimally invasive treatment using partial-coverage restorations fabricated with lithium disilicate.

Vahidi F. J Prosthodont 2019;28:737–742. References: 28. Reprints: Farhad Vahidi, fv1@nyu.edu — Steven Sadowsky, USA