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Facial acquisition by dynamic optical tracked laser imaging: a new approach☆

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Summary Three-dimensional capture of the surface of soft tissue is a desirable support for documentation and therapy planning in plastic and reconstructive surgery concerning the complex anatomy of the face, particularly cleft lip and palate (CLP). Different scanning systems are used for capturing facial surfaces. These systems are mostly based on a static linear measuring arrangement. Established systems work on the basis of coded white light or linear laser triangulation and digital stereophotogrammetric approaches. Shadowing effects occur with these devices. These effects may be avoided by a radical new approach first used in automotive industries that employs a mobile, flexible handheld laser scanner with simultaneous registration by optical tracking. The aim of this study was to assess the suitability of this scanner for surgical procedures on the human face in operating theatre. Five babies aged about 3 months with cleft deformities (one CLP, one bilateral CLP, three isolated cleft lips) were captured directly: twice preoperatively, twice postoperatively and twice after 7 days. An industrial standard specimen and two plaster cast masks of CLP babies were taken and subsequently measured to assess reliability and validity of the device. Masks were measured to reflect the complex surface of the cleft deformity. Data evaluation was done with respect to completeness of the data sets, as well as reliability and validity of the system. Missing data

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caused by shadowing could be avoided in all images. Even complex areas with undercuts could be reproduced completely and precisely with an accuracy in the sub-millimetre range.

Three-dimensional (3D) capture of the surface of soft tissue is a desirable support for documentation and therapy planning in plastic and reconstructive surgery concerning the complex anatomy of the face, particularly cleft lip and palate (CLP). Obtaining reliable, precise 3D surface models is a constant challenge. Various 3D scanning devices have been developed for contact-free acquisition of the surface of soft tissue. These systems are mostly based on a static linear measuring arrangement. Established systems work on the basis of coded white-light,[1,2] linear laser triangulation[3–5] or digital stereophotogrammetric[6,7] approaches. Shadowing effects due to undercuts occur in these devices; data quality in complex parts (e.g. ears, nostrils, inside the cleft region) can be limited. Additional, partial images from different angles must be taken to compensate for these missing surface parts. The number of additional images depends on the complexity of the measured area. These problems may be avoided by a completely new approach first used in automotive industries that employs a mobile, flexible handheld laser scanner. Gathered data can be composed to one 3D image of the measured face in real time by simultaneous registration of the position of the handheld device. This allows immediate control of visual data and instant adjustment. The aim of the present study was to test the clinical application of this flexible device for 3D spherical imaging in cleft lip morphology.

Material and methods

Patients

Five babies aged about three months with CLP deformities (one CLP, one bilateral CLP, three isolated cleft lips) were measured. Two complete facial images were taken preoperatively, two directly after surgery, and another two images 7 days' later, after suture removal. In two cases with complete clefts, additional combined intra- and extraoral plaster masks[8] were taken preoperatively to determine the reliability of the scanner in objects with a typical complex surface. Five iterative scans of the same plaster mask were analysed to test reproducibility.[1] Images were acquired by the same person (B. I. B. B.).

Accuracy of the T-Scan system

The precision of the T-Scan scanning device was determined by measuring an industrial standard calibration specimen (Barbell TK80 HF 200/111 by QS Grimm GmbH certified by the German calibration service DKD-K-11901). The calibration procedure was based on the German calibration norm VDI 2634.[9] A commercially available static linear laser scanner was used (Vivid 900 Scanner/VI-900 Konica Minolta Holdings Inc., Tokyo, Japan)[10] for comparison with a conventional scanning system.

The study protocol was approved by our institutional review board. Informed consent was obtained from the patients' parents. Use of the scanning device followed the principles outlined in the Declaration of Helsinki.

Scanning system and tracking device

The flexible scanning system was a handheld triangulation scanner. The facial surface was captured by a laser beam (670 nm, laser class 2) and measured at high scanning frequencies. The laser beam was linearly oriented by a polygon mirror. The measurement distance was calculated using the triangulation principle, in which distance conversion of an azimuth difference between reflected light and the output position of the laser was done. The handheld device had 29 infrared markers, three of which were determined for the exact spatial position using an optical tracking system. The technical data of the device (TSCAN®, Steinbichler Optotechnik GmbH, Neubeuern, Germany)[11] were as follows: measuring depth 75 mm, scan width 90 mm, mean measuring distance 83 mm, scan frequency 10–140 Hz, sampling rate of distance measurement 10 kHz, resolution of distance measurement 1 μm, accuracy of distance measurement +/− 30 μm, point density in scan direction 0.14–1.96 mm, sensor weight <1500 g, sensor dimensions 185 × 199 × 145 mm, standard cable length scanner-PC 9 m, lateral resolution 0.1 mm, laser type: diode, wavelength 670 nm, laser class 2. The tracking system was the OPTOTRAK PRO 1000® (Northern Digital Inc., Ontario, Canada). The OPTOTRAK System has an approximate weight of 19 kg, and a dimension of 1126 × 200 × 161 mm. The measurement volume is shown in Figure 1. The measurement volume can be indicated directly on the object by means of laser pointer lines. The measured 3D image can be

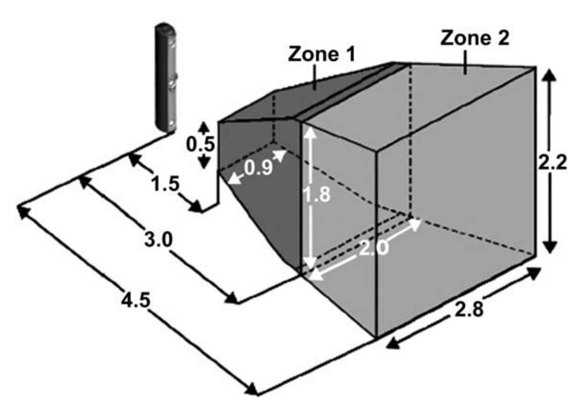

Figure 1 Measurement volume of the OPTOTRAK PRO 1000® (Northern Digital Inc., Ontario, Canada) is shown. The camera is on the left. The optimal measuring distance between object and tracking camera is 1.5–3 m in zone 1. These distances are adapted to the demands of our operating theatres.