Recording of Natural Head Position Using Stereophotogrammetry: A New Technique and Reliability Study

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The purpose of this study was to develop a technique to record physical references and orient digital mesh models to a natural head position using stereophotogrammetry (SP). The first step was to record the digital mesh model of a hanging reference board placed at the capturing position of the SP machine. The board was aligned to true vertical using a plumb bob. It also was aligned with a laser plane parallel to a hanging mirror, which was located at the center of the machine. The parameter derived from the digital mesh model of the board was used to adjust the roll, pitch, and yaw of the subsequent captures of patients' facial images. This information was valid until the next machine calibration. The board placement was repeatable, with standard deviations less than 0.1° for pitch and yaw angles and 0.15° for roll angles.

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Natural head position (NHP) is regarded as a reproducible head position in an upright posture when a patient is focusing at a distant point at eye level.[1,2] Since its introduction in the 1950s, it has been regarded as an essential component in orthodontic and orthognathic diagnosis and surgical planning.[3-6] Approximation of the NHP in the computer environment is traditionally based on anatomic landmarks and planes identified from various imaging modalities ranging from 2-dimensional radiographs to 3-dimensional (3D) imaging based on computed tomographic (CT) scans. Nevertheless, application of this approach is limited in some demanding situations, such as facial scoliosis and hemifacial microsomia in which the existing facial imbalance complicates the identification of planes. Alternatively, the recording can be performed using *1)* laser-assisted surface marking during CT image acquisition,[7-9] *2)* direct recording of the NHP using orientation sensors[10,11] (integrated triaxial accelerometers and magnetometers) from which the readings are applied to reorient the CT virtual model, *3)* inclinometers,[12] and *4)* a facebow equipped with a spirit level.[13]

Currently, stereophotogrammetry (SP) machines are readily available for the assessment of dentofacial deformity. These machines provide a noninvasive photographic-quality 3D capture of object surfaces with high accuracy.[14,15] Because calibration of the device usually does not consider any physical reference, the SP system can capture only patients' surface morphology irrespective of anatomic orientation. The resulting 3D facial surfaces are tilted to an unknown orientation. Therefore, an additional calibration step is needed to correct the orientation. This orientation calibration could be achieved using some physical references, such as true vertical and mirror orientation. The aim of this report is to describe a technique to record physical references and its reliability.

Materials and Methods

In this study, the 3D soft tissue capture was performed using 3dMDface (3dMD, Atlanta, GA), which allows reproduction of the 3D coordinates of the same still object on different scans with high repeatability

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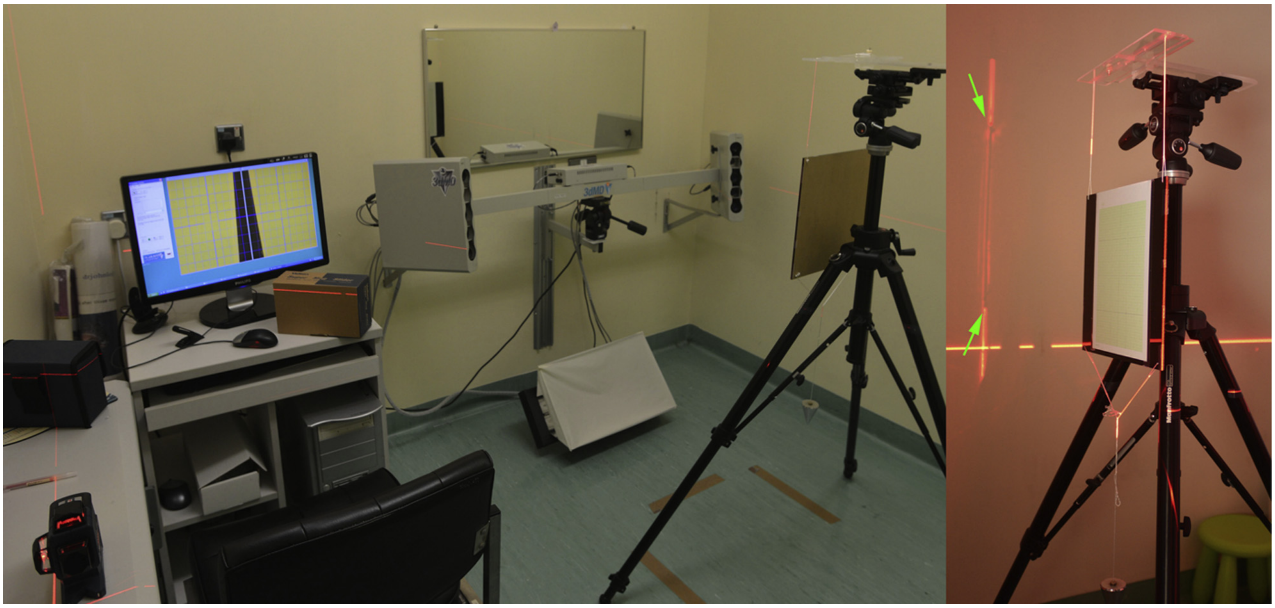

FIGURE 1. *Left*, The hanging reference board is placed at the capturing position, which is aligned parallel to the mirror using the alignment laser. The graph paper on the board indicates the roll angles needed to rotate the digital models back to true vertical. *Right*, When the board is aligned to face the mirror, the laser beam creates shadows (*green arrows*) on the right wall from the threads at which they overlap. The size of the board shadow is minimal.

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(for each machine calibration). The measured repeatability accuracy for face scanning has been found to be 0.016676 and 0.080488 mm for no-pose and pose changes, respectively.[15] This means that the computed 3D coordinates of the same still object surface will be the same among different scans. This property enables

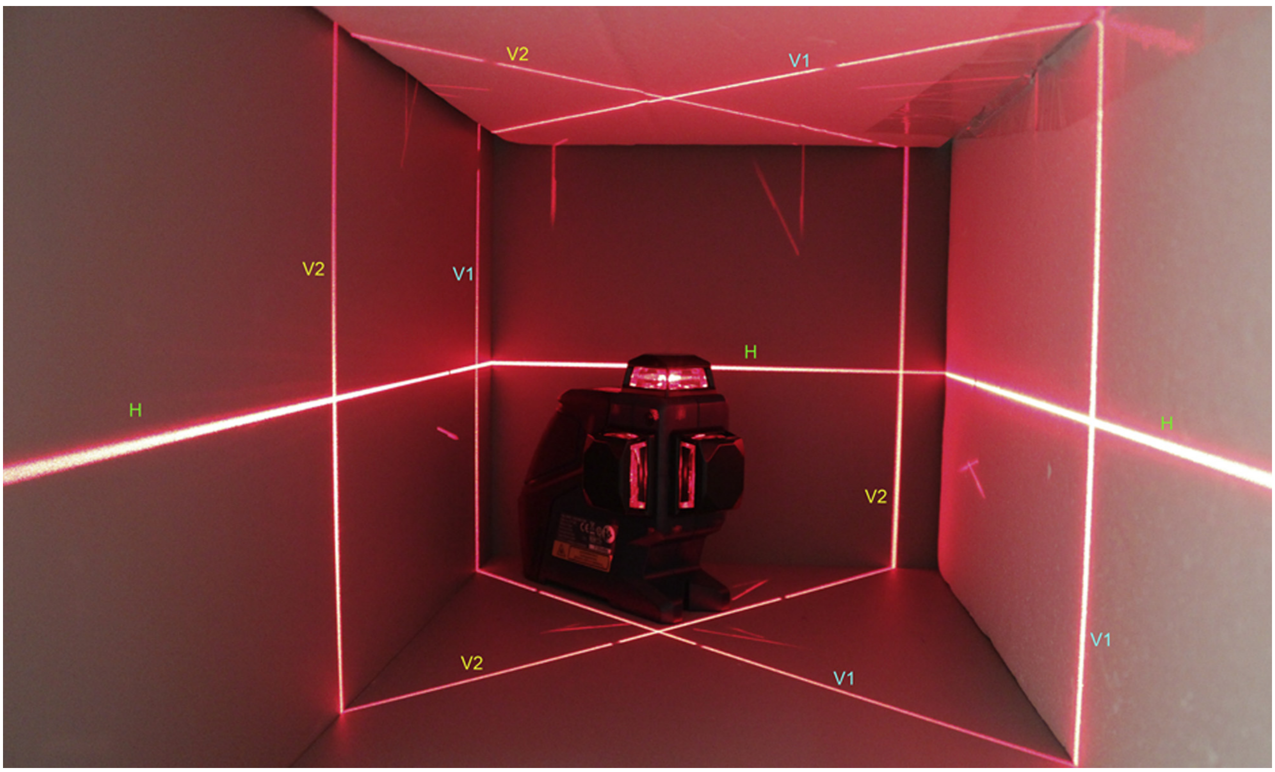

FIGURE 2. A 360° 3-plane leveling and alignment laser alignment laser is adopted for alignment. It projects laser beams along 3 planes that are perpendicular to one another: true vertical (*V1*, *V2*) and horizontal (*H*).

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