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An in-vitro study to assess the feasibility, validity and precision of capturing oncology facial defects with multimodal image fusion

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ABSTRACT

Aim: Assess the feasibility, validity and precision of multimodal image fusion to capture oncology facial defects based on plaster casts.

Methods: Ten casts of oncology facial defects were acquired. To create gold standard models, a 3D volumetric scan of each cast was obtained with a cone beam computed tomography (CBCT) scanner (NewTomVG). This was converted into surface data using open-source medical segmentation software and cropped to produce a CBCT mask using an open-source system for editing meshes. For the experimental model, the external facial features were captured using stereophotogrammetry (DI4D) and the defect was recorded with a custom optical structured light scanner. The two meshes were aligned, merged and resurfaced using MeshLab to produce a fused model. Analysis was performed in MeshLab on the best fit of the fused model to the CBCT mask. The unsigned mean distance was used to measure the absolute deviation of each model from the CBCT mask. To assess the precision of the technique, the process of producing the fused model was repeated to create five models each for the casts representing the best, middle and worst results.

Results: Global mean deviation was 0.22 mm (standard deviation 0.05 mm). The precision of the method appeared to be acceptable although there was variability in the location of the error for the worst cast.

Conclusion: This method for merging two independent scans to produce a fused model shows strong potential as an accurate and repeatable method of capturing facial defects. Further research is required to explore its clinical use.

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Introduction

A diagnosis of head and neck cancer has a major psychological and physical impact on patients. In 2014, over 11,000 new cases of head and neck cancer were reported in the United Kingdom.[1] Approximately half of head and neck cancer patients will undergo major surgical resection.[2] This radical surgery can prolong survival time but will also result in a substantial loss in quality of life due to deformity or disability.[3] The resulting defects may be reconstructed with surgery or rehabilitated with removable prostheses.

Conventional facial prostheses are fabricated on plaster casts formed from an impression of the defect which captures both the facial border and the depth of the defect. Conventional impressions have multiple disadvantages including inaccuracies due to soft tissue deformation under the weight of the material or due the patient's reflex movements.[4] Patient anxiety or discomfort may result from covering the face or restricting the airway during the impression procedure.[5] Additionally, rehabilitating orbital defects can be challenging when matching the unaffected side because eyes must be closed to take the impression.[4]

Facial prostheses require multiple replacements during a patient's lifetime for various reasons including colour deterioration, poor maintenance, degradation of the materials or poor fit.[6] Additionally, longevity of facial prostheses will vary depending on the retention method. Reported serviceability is often within the range of 6–18 months however implant retained prostheses typically remain in service for longer than those adhesively retained.[6] A UK based survey of maxillofacial laboratory staff in 2002 estimated over 2000 patients required facial prostheses annually.[7] Therefore, there is a clinical need to devise an accurate, easily reproducible and less invasive method of recording facial defects.

Various studies have employed a variety of different three-dimensional (3D) imaging techniques in attempt to overcome the disadvantages of conventional impressions through optical,[4] laser,[5] and stereophotogrammetry systems.[8] These reports allude to the significant potential benefits of using 3D facial imaging as an alternative to conventional impressions through improved patient comfort, reduced invasiveness, efficiency of data collection, and enabling of computer aided design and computer aided manufacturing (CAD/CAM) processes.[4,5] They also overcome the limitations associated with the use of computed tomography or magnetic resonance imaging such as patient radiation exposure or artefacts related to metal objects e.g. implants.[9] A survey of UK maxillofacial prosthetists and technologists in 2007 found that 31% of the respondents were employing digital technologies during the design or manufacture of maxillofacial silicone prostheses.[6] Their positive reflections included the perceived accuracy of these procedures and avoidance of patient impressions.[6]

Stereophotogrammetry systems are becoming more commonplace within the hospital setting. These take images of objects from multiple viewpoints in a synchronised manner and have the benefits of a short capture time and clinically acceptable accuracy.[8] However, as they are unable to capture deep defects this method is not optimised for use with oncology patients. Structured light 3D scanners work by projecting a dense pattern onto a target, and viewing the data using calibrated cameras. In contrast to stereophotogrammetry, this technique is robust to less textured regions and is also more accurate in selecting corresponding points in the stereo image-pairs. This in turn allows a narrower baseline separation between the cameras with no loss in precision. Consequently, a hybrid technique using an inexpensive structured light scanner to supplement the data acquired by stereophotogrammetry may facilitate the capture of sufficient accurate data for prosthetic rehabilitation.

Therefore, this *in vitro* study aimed to assess the feasibility, validity and precision of using multimodal image fusion to capture oncology facial defects based on plaster casts. The external facial features would be captured with stereophotogrammetry and fused with the internal defect imaged through optical scanning.

Materials and methods

Ethical approval was obtained from the Dental Research Ethics Committee at the University of Leeds. Ten historical plaster casts of a variety of oncology facial defects were acquired from the maxillofacial laboratories within Leeds Teaching Hospitals and Bradford Teaching Hospitals. The samples varied in size and degree of undercut and included four nasal defects, five orbital defects and one combined defect.

To create the gold standard models, a 3D volumetric scan of each cast was taken with a cone beam computed tomography (CBCT) scanner (NewTom VG, NewTom, Verona, Italy) (0.3 mm voxel size). This was converted into surface data using open-source medical segmentation software (ITK Snap, http://www.itksnap.org/) and cropped to produce a CBCT mask using an open-source system for editing meshes (MeshLab, http://meshlab.sourceforge.net/).

To create the experimental model, the external facial features were first captured using stereophotogrammetry (DI4D, Hillington, Glasgow.). Subsequently, the defect was imaged with a custom optical structured light scanner comprising two off-the-shelf IDS uEye LE monochrome 1 MP cameras (IDS, Obersulm, Germany) and a digital light processing projector Optoma PK201 (Optoma Europe Ltd, Watford, UK). This was then aligned to the external facial features, merged and resurfaced using MeshLab to produce a single fused model of the external facial features and defect (Fig. 1).

Analysis was performed on the best fit of the experimental model to the CBCT mask. The two meshes were aligned based on the iterative closest point (ICP) algorithm and assessed for global absolute deviation.[10] The unsigned mean distance between the meshes was used to measure the absolute deviation of each fused model from the CBCT mask. Colour error maps were also produced for each CBCT mask to demonstrate points on the fused model which were within different distance parameters.

Two fused models had missing data due to extreme undercuts. As the subsequent prostheses would not need to obturate this area, the corresponding casts were marked by a maxillofacial prosthetist to identify the prosthesis margins. The unsigned mean distance was reassessed excluding data

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