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# Proposal for the Fusion of Ultrasound and Computed Tomography Images for Image Shift Correction in Craniomaxillofacial Soft Tissue Surgery

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**Abstract:** Surgical navigation has greatly improved the accuracy of craniomaxillofacial bone surgery and is widely used in the clinic. However, during surgery, craniomaxillofacial soft tissue is always deformed due to traction and compression, which leads to intraoperative image drift. This, in turn, impacts navigation accuracy. In order to improve navigation accuracy, this technical note presents a preliminary proposal for fusion imaging technology, which combines ultrasound and computed tomography to address navigational image drift in craniomaxillofacial soft tissue surgery.

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**Key Words:** Computed tomography, craniomaxillofacial soft tissue, image fusion, navigation, ultrasound

Craniomaxillofacial surgery is anatomically complex and used for special therapeutic purposes.[1,2] A major goal for surgeons is to complete surgical procedures safely and accurately, and with minimal invasion. Due to the inflexibility of bone tissue, which is similar to a rigid body, modern digital technologies, such as virtual surgery and surgical navigation, have greatly improved the accuracy of craniomaxillofacial bone surgery. These technologies have wide clinical applications, including in surgeries for craniomaxillofacial fracture, temporomandibular joint arthroplasty, bone tumor resection, and contour trimming.[3–6] However, during surgery, craniomaxillofacial soft tissues can easily deform and cause image drift. Thus, the preoperative image may not reflect the actual and real-time intraoperative soft tissue morphology, and this prevents lesions and soft-tissue deformations from being measured intraoperatively in real-time. These complications may easily lead to substantial navigation and positioning errors that limit the utility of surgical navigation technologies for use in soft tissue surgery. Current approaches to address this problem include intraoperative computed tomography (CT)/magnetic resonance imaging examinations and ultrasound image but have limited efficacy for time-consuming, radiation exposure, and low image quality.

This technical note presents a proposed method for the fusion of ultrasound and CT images for image shift correction in craniomaxillofacial soft tissue surgery and serves as a proposal for the treatment of foreign body and tumor in the craniomaxillofacial deep space.

## MATERIALS AND METHODS

### Experimental Equipment

A Mindray M7 Series portable color Doppler ultrasound system (Shenzhen Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China) was used to acquire two-dimensional (2D) ultrasound images. A Polaris optical positioning system (Northern Digital Incorporated, Waterloo, Ontario, Canada) was used to acquire position and orientation data from the 2D ultrasound images. A 64-slice CT scanner (Phillips Inc, Amsterdam, the Netherlands) was used to acquire CT images.

### Data Acquisition

Freestyle scanning with an ultrasound probe guided by a Polaris optical positioning system (Northern Digital Incorporated) was used to acquire 2D sequential ultrasound images containing spatial positional information. The CT scan range was from the calvarium to the level of the hyoid bone, with a layer thickness of 1.25 mm; the data were stored in DICOM format.

### Image Registration and Fusion

First, the CT and ultrasound image data were imported into a self-developed image fusion algorithm, called mi-local binary pattern. Then, image co-registration was completed using pattern recognition to obtain a fusion display of the ultrasound and CT images, thereby achieving the integration of multimodal imaging information.

### Clinical Application

To verify the feasibility of the method and system, CT and freestyle ultrasound scanning under optical positioning were performed in patients with a foreign body in their face (Fig. 1A-B) and a parotid mass (Fig. 1C-D). After integration, the system was able to operate normally under the on-site supervision of oral and maxillofacial surgeons, sonologists, and engineers. This allowed for an ultrasound image of patient lesion areas to be obtained.

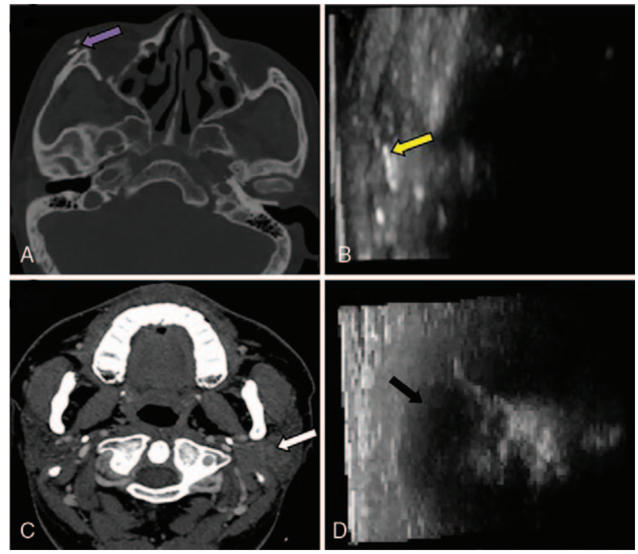

**FIGURE 1.** (A) The original CT scan image of a foreign body (indicated by purple arrow) in the face. (B) The location of the foreign body (yellow arrow) in the ultrasound image. (C) An enhanced CT of a left parotid mass (white arrow). (D) An ultrasound image of the parotid mass (black arrow). CT, computed tomography.

The data from each ultrasound modality and CT image were imported into the image processing software Medical Image Processing, Analysis, and Visualization (Bethesda, Maryland, USA). Each image was preprocessed according to the characteristics of the respective data. Finally, the registration was completed with mi-local binary pattern to obtain a fusion display of the ultrasound and CT images, thus achieving the integration of multimodal imaging information.

## RESULTS

The connected and assembled system operated properly, and the time required for the entire operation (including installation and initial settings) was less than 15 minutes. These parameters met the basic requirements for clinical use under physician supervision. Furthermore, the preliminary implementation of ultrasound and CT image fusion of craniofacial soft tissue was successful. The errors of image fusion for facial foreign body and parotid mass were 1.43 mm and 2.23 mm, respectively, as determined by measuring the corresponding point, which is shown in Figure 2A and B.

## DISCUSSION

In recent years, a crucial objective in maxillofacial surgery is the evaluation and the estimation of the soft tissues. Soft-tissue contour deficiencies depend on various origins including esthetics, congenital and post-trauma asymmetries, post-tumor defects, and chronic wound sequelae. Reconstructions or repairs are still a challenge today for a satisfactory aesthetic result should be obtained with the harmony of skeleton and soft tissue cover.[7–9]

Recent methods for surgical navigation have greatly improved the accuracy of craniomaxillofacial bone surgeries, including bone fracture, temporomandibular joint arthroplasty, bone tumor resection, and contour trimming.[3–6] For craniomaxillofacial soft tissue,

 

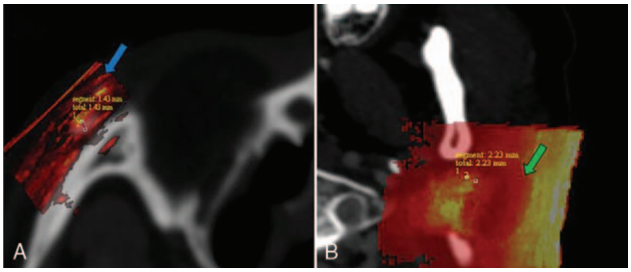


FIGURE 2. A display of the CT and ultrasound fusion image. (A) A CT and ultrasound fusion image of a foreign body; the blue arrow indicates the superimposed display area of the 2 images. (B) A CT and ultrasound fusion image of a parotid mass; the green arrow shows the superimposed display area for the parotid mass. CT, computed tomography.

deformation may easily occur and can cause image drift during navigation procedures. These complications may easily result in large navigation and positioning errors that limit the application of surgical navigation technology towards soft tissue surgery.

In recent years, real-time ultrasound image fusion techniques have improved and are currently widely available. These techniques offer several advantages, including the acquisition of real-time images without exposing patients to radiation.[10–12] The presented procedure used an algorithm to fuse ultrasound and CT images based on an optical positioning system. This algorithm can identify deformations in real-time and therein use the spatial positional information of the soft tissue to compensate for the registration error caused by deformations. This, in turn, can substantially improve navigation accuracy. Compared to the recently proposed specialized methods, it can be observed that our procedure achieves the best accuracy of 1.43 mm, which shows that it significantly outperforms the other methods.[13,14]

Although the present study achieved some preliminary clinical results, some limitations remain. First, oral and craniomaxillofacial soft tissues lack relatively fixed and clear anatomical markers, especially when registering masses in craniomaxillofacial soft tissue images. Consequently, it is difficult to find common landmarks at the same level between ultrasound and CT, which may increase registration error. Second, the manual freestyle scanning method used to acquire the ultrasound data may lead to inconsistent thickness intervals for the obtained 2D ultrasound data, and therein reduce the quality of the reconstructed image. Finally, reconstructing the three-dimensional position from the 2D ultrasound image is a relatively lengthy process. Future research is needed to address these limitations and to evaluate the system accuracy and reproducibility of image fusion from this proposed procedure.

In conclusion, this procedure represents an interesting approach to navigate intraoperatively through a patient without the need for additional radiation exposure. The preliminary implementation of ultrasound and CT image fusion indicates that it is capable of guiding the self-developed navigation system in oral and craniomaxillofacial soft tissue surgery. However, for this technique to be accepted as a viable alternative, there remains a need for larger trials that evaluate objective metrics of accuracy and efficacy. Consequently, we plan to expand upon this technical note in a future study to rigorously test the efficacy and generalizability of our approach, and promote the use of ultrasound and CT image fusion to improve clinical outcomes for soft tissue surgery, especially in the CMF deep space surgery.

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# Craniosynostosis of the Metopic Suture in a Patient With CADASIL/Lehman Syndrome

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**Abstract:** A 3-month-old patient presented for evaluation by plastic surgery with marked trigonocephaly and was subsequently

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