Technical Issues of Image Guided Surgery

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Image-Guided CMF-Surgery

An incomplete list of systems...

- ARTMA Virtual Patient
- RoboDent System
- DenX IGI System
- Drill Guides (Materialise, T. Fortin et al.)
- Modification of commercial systems like the BrainLAB suite or the Medtronic TREON
- ... and VISIT
Reviving old VHS - Tapes: VISIT in action

Challenges from a technical point of view

- Imaging – CT protocols & handling of artefacts
- Patient – to - image registration
- Image processing issues – visualization & segmentation
- Hardware for image-guided CMF surgery
- Workflow optimization
- What's about to come?
- Non-technical challenges ...
Imaging

- CT is the modality of choice for dental and CMF surgery
  - Streak artefacts stem from the reconstruction process and are difficult to avoid or to be removed
  - Pantomography is strongly dependent on patient positioning due to the strong perspective and the tomographic distortion of the image
  - CBCT introduces other artefacts such as truncation and ring artefacts
Artefacts in CBCT

Truncation- and ring-artefacts are common ...
Quantitative CT

Planning in VISIT

- Planning of implant channels based on available bone volume and density is rather straightforward.
- For extraoral implants, a more sophisticated interface is necessary.

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Tracking & Registration—a Link to the Real World

• Registration: Finding a transformation between the coordinate system of a volume image and the real world
• Tracking: Maintaining that registration by measuring motion in 3D by
  • optical tracking
  • electromagnetic probe
  • alternative techniques

J. Hummel et al., Med Phys 29(10):2205-2212, 2002
Key issues in Tracking

• Accuracy and resolution: Optical trackers are rather accurate and still superior to EM probes
• Reliability: A free line of sight for an optical tracker always be maintained
• Handling: Trackers are cumbersome in general; passive systems have a higher acceptance rate than active (=wired) systems, but are less robust.
• Sterilizability: Autoclavation of electronics is difficult, ETO is expensive and time-consuming
Patient to Image Registration

Point to point registration (Horn) using at least three markers and a point probe error 0.7 +/- 0.15 mm

Some experiences

- Minimally invasive insertion of titanium microscrews is feasible; the markers stay stable for several weeks
- Increasing the number of markers beyond 3 screws does not influence registration accuracy
- Exact localisation of screwhead centroids is necessary
- Mobility of mucosa in atrophic patients caused inaccuracies when using splint-type solutions, even if residual dentition is available

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Image Processing: Segmentation

Segmentation is not exact – Identification of surfaces depends on algorithms used
Alternative techniques

Surface registration: Highly dependent on the quality of surface segmentation and the presence of outliers

- Surface scanning by laser ranging is hampered by the small visible area of the mucosa
- Stab incisions are cumbersome, but give good results

Splint techniques

- Problematic in completely edentulous patients
- Residual elasticity of 2-component molding materials is recognizable
- Segmentation of molding material and mucosa sometimes difficult

Surface Scanning

- Has a long history in frameless stereotaxy
- Complicated for fully intraoral interventions


Tracking technologies for CMF & oral surgery

- 32 implants, 5 patients after tumor resection and primary reconstruction

- Accuracy:
  - top 1.0 +/- 0.5 mm
  - bottom 1.3 +/- 0.9 mm

Challenges in tool design

- Sterilizable electronics are cumbersome, autoclavation is difficult.
- Passive markers somewhat solve the problem and are handy, but provide less accurate results when being contaminated with blood.
- Tool geometry (and size) is crucial.

An early academic effort

Hybrid Tracking


- Combination of electromagnetic and optical sensors to overcome the drawbacks of both technologies
Looking back - Implant insertion - 2000

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Implant insertion after hemimaxillectomy

Sealing of the nasopharynx with an obturator prosthesis after radical resection of squamous cell carcinoma

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Restoration after ablative tumor resection

- Surgical removal of an osteosarcoma in the mandible
- Implant insertion in a scapula flap after reconstruction


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Minimally invasive implant insertion

Comparison of VISIT and the Medtronic TREON system. Accuracy ranges from 0.6 +/- 0.5 to 1.0 +/- 0.5 mm for both systems

Medical Augmented Reality

Technology of image injection

Linking navigation and augmented reality
Conclusions & Outlook

Research directions for Computer Aided Surgery in the CMF-area include

- Technical developments concerning TRE …
- Developments for optimized workflow and cost including socioeconomic research
- Evaluation of suitable clinical applications
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