Int. J. Oral Maxillofac. Surg. 2017; xxx: xxx–xxx
http://dx.doi.org/10.1016/j.ijom.2017.05.003, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Orthognathic Surgery

Computer-assisted orthognathic surgery: evaluation of mandible registration accuracy and report of the first clinical cases of navigated sagittal split ramus osteotomy

H. Naujokat, M. Rohnen, J. Lichtenstein, F. Birkenfeld, M. Gerle, C. Flörke, J. Wiltfang
Department of Oral and Maxillofacial Surgery, University Hospital of Schleswig-Holstein, Campus Kiel, Kiel, Germany

H. Naujokat, M. Rohnen, J. Lichtenstein, F. Birkenfeld, M. Gerle, C. Flörke, J. Wiltfang: Computer-assisted orthognathic surgery: evaluation of mandible registration accuracy and report of the first clinical cases of navigated sagittal split ramus osteotomy. Int. J. Oral Maxillofac. Surg. 2017; xxx: xxx–xxx.

Abstract. Intraoperative navigation is a helpful tool in complex anatomical regions or procedures. The mobility of the mandible in relation to the skull base limits the use of navigation tools on the lower jaw if the reference device is installed on the forehead. A new workflow that allows navigation-assisted sagittal split osteotomy in orthognathic surgery using a separate non-invasive mandibular registration technique has been developed. An evaluation of accuracy in different anatomical regions and with different registration techniques was performed on skull models and skulls with movable mandibles. The mean inaccuracy was 1.51 mm, with no significant difference between anatomical sites. Using a splint-based reference device allows the movable mandible to be registered independently from the midface. Registration using metal points in the splint provides higher accuracy than using interdental anatomical landmarks. The workflow could be transferred successfully to patient treatment. Navigation-assisted osteotomy by Obwegeser–Dal Pont technique was performed without any complication in six patients. The mean deviation from the planned osteotomy line was 1.52 mm. The navigated sagittal split ramus osteotomy seems to be a suitable technique to increase patient safety.

Key words: computer-assisted surgery; orthognathic surgery; registration of the mandible; intraoperative navigation; sagittal split ramus osteotomy; accuracy.

Accepted for publication 5 May 2017

0901-5027/000001+07

The sagittal split ramus osteotomy (SSRO) according to the Obwegeser–Dal Pont technique is commonly used in orthognathic surgery. The advantage of large bone contact surfaces is accompanied by the risk of severe nerve injury and 'bad split' fractures[1]. The anatomy of the ascending ramus is complex and the surgical approach is limited. To address restrictions like these, computer-based diagnostics, surgical planning, and intraoperative navigation have become established techniques in oral and maxillofacial surgery, as well as in craniomaxillofacial surgery[2].

Intraoperative navigation allows the visualization of registered instruments within three-dimensional images of the patient's anatomy. The accuracy of navigation plays a fundamental role in treatment success. Different components influence the accuracy of the navigation system. The fiducial markers are usually installed on the forehead and registration is performed using hard tissue landmarks or surface registration in the midface. Using anatomical hard tissue landmarks, the accuracy increases when the three-dimensional distance between the registration points is larger[3]. Laser surface registration is easier and faster, but is accompanied by higher inaccuracy[4,5]. Another aspect that influences accuracy is the distance of the fiducials from the anatomical site to be operated on. Studies have shown that accuracy increases when the centre of the fiducials is installed closer to the target of surgery[6,7]. Some authors have even reported a linear correlation[3].

It is not yet clear whether the distance from the mandibular angle to the forehead affects the accuracy of the navigation device. However, the main limitation when using the navigation technique for the lower jaw is that the mandible is movable. Performing registration in the midface and installing the fiducials on the forehead is not suitable for mandibular procedures. In such cases, it would be appropriate for the fiducials to be installed on the lower jaw. Some authors have addressed this problem by implanting three transcutaneous positioning screws in the mandible as navigation markers[8]. In implant surgery, fiducials in the drilling template for the mandible are used to address this problem[9].

The aim of this study was to develop a workflow that allows navigation-assisted SSRO in orthognathic surgery of the movable mandible using a separate non-invasive mandible registration technique.

Materials and methods

Evaluation of accuracy at the mandibular angle

Five skull models with fixed mandibles were printed (ZPrinter 350; Z Corporation, Rock Hill, SC, USA). These were based on the data of five random patients who had undergone cone beam computed tomography (CBCT) (KaVo 3D eXam K1-10-3-0; KaVo GmbH, Biberach, Germany; field of view 16 × 13 cm, voxel size 0.3 mm) in preparation for orthognathic surgery. Measurement points were inserted in the mandibular angle and the oblique line bilaterally with gutta-percha points (Dentsply, Konstanz, Germany). Hard tissue peri-orbital and splint-based occlusal landmark registration points were also added with gutta-percha points (Fig. 1A). Once prepared as described, all skulls were examined by CBCT using the same parameters as before. The data were processed in navigation software (iPlan 3.0; Brainlab AG, Feldkirchen, Germany) by digitally marking the measurement points and registration points (Fig. 1B).

In an experimental setup, registration was done with the hard tissue landmarks and splint-based registration points. The registration device was applied to the forehead. The pointer was placed exactly on the measurement points and the deviation from the digital marked measurement point was ascertained on the navigation device (Kolibri 2.0; Brainlab AG, Feldkirchen, Germany) by a second blinded investigator. The examination was repeated three times for each skull model; the registration procedure was performed each time.

Registration of the mandible

Three skulls with movable mandibles (Institute of Anatomy, University of Kiel, Germany) were marked with metal points (diameter 0.7 mm; Kugel-Rollen AG, Röthlein, Germany), which were fixed with Triad Gel (Dentsply, Konstanz, Germany). The points were placed in five different anatomical areas on the mandible (vestibular osteotomy at the corpus, ascending ramus osteotomy, lingual horizontal osteotomy, mandibular angle, front) (Fig. 2A). A splint based on the occlusal surface of the mandible teeth was fabricated and marked with six metal points. The prepared skulls were examined with the integrated splint in place by CBCT (voxel size 0.3 mm). The data were processed in navigation software by digitally marking the measurement points. Registration was performed with three different methods, using either: (1) the metal points on the oblique line, (2) interdental anatomical alveolar bone, or (3) splint-based metal points. The registration device was fixed to the splint, which itself was attached to the mandible by wires and orthodontic rubber bands (Fig. 2B).

In an experimental setup, the pointer was placed exactly on the measurement points and the divergence from the digital marked points was assessed by the second blinded investigator. The examination was repeated three times for each skull with the three different registration methods.

Patient treatment

This prospective study was approved by the Ethics Committee of the University Hospital Schleswig Holstein, Kiel. Six

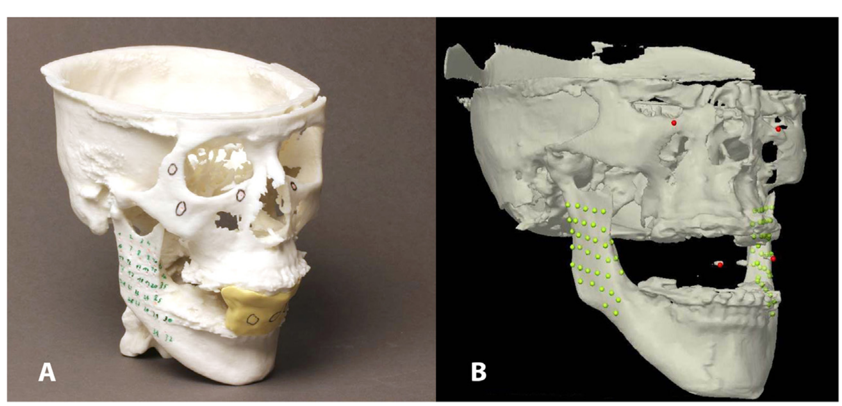

Fig. 1. Printed skull models with fixed mandibles were prepared with radiopaque gutta-percha points. Measurement points were inserted in the mandibular angle and the oblique line bilaterally, and hard tissue peri-orbital and splint-based occlusal landmark registration points were added (A). The measurement points (green) and registration points (red) were marked digitally on the cone beam computed tomography image (B).

Please cite this article in press as: Naujokat H, et al. Computer-assisted orthognathic surgery: evaluation of mandible registration accuracy and report of the first clinical cases of navigated sagittal split ramus osteotomy, *Int J Oral Maxillofac Surg* (2017), http://dx.doi.org/10.1016/j.ijom.2017.05.003