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Clinical and radiographic evaluation of a computer-generated guiding device in bilateral sagittal split osteotomies

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ABSTRACT

The bilateral sagittal split osteotomy (BSSO) is one of the main orthognathic surgery procedures used for managing skeletal mandibular excess, deficiency or asymmetry. It is known to be a technique-sensitive procedure with high reported incidences of inferior alveolar nerve injury, bad splits and post-surgical relapse. With the increasing use of computer-assisted techniques in orthognathic surgery, the accurate transfer of the virtual plan to the operating room is currently a subject of research. This study evaluated the efficacy of computer-generated device at maintaining the planned condylar position and minimizing inferior alveolar nerve injury during BSSO. The device was used in 6 patients who required isolated mandibular surgery for correction of their skeletal deformities. Clinical evaluation showed good recovery of the maximal incisal opening and a reproducible occlusion in 5 of the 6 patients. Radiographic evaluation showed better control of the condyle position in both the vertical and anteroposterior directions than in the mediolateral direction. The degree of accuracy between the planned and achieved screw positions were judged as good to excellent in all cases. Within the limitations of this study and the small sample size, the proposed device design allowed for good transfer of the virtual surgical plan to the operating room.

1. Introduction

The bilateral sagittal split osteotomy (BSSO) is one of the main orthognathic surgery procedures used for managing skeletal mandibular excess, deficiency or asymmetry. It is known to be a technique-sensitive procedure with high reported incidences of inferior alveolar nerve injury (Bothur and Blomqvist, 2003; Teltzrow et al., 2005; D'Agostino et al., 2010; Iannetti et al., 2013), bad splits (Teltzrow et al., 2005; Chrcanovic and Freire-Maia, 2012) and post-surgical relapse (Ow and Cheung, 2009).

Post-surgical relapse has been classified into immediate and delayed relapse. The immediate relapse has been mainly attributed to improper seating of the mandibular condyles in the glenoid fossae whereas delayed relapse has been attributed to unstable occlusion, inadequate fixation and condylar resorption. Various authors have stressed avoiding condylar displacement and have suggested intraoperative guidance of the condylar position (Ayoub et al., 1997; Reyneke and Ferretti, 2002; Emshoff et al., 2003; Frey et al., 2007).

Different condylar positioning devices (CPDs) have been investigated for effectiveness in re-establishing the preoperative condylar position following BSSO with contradicting outcomes as regards to both skeletal stability and temporomandibular disorders (TMD). These devices ranged from intraoperative monitoring devices; such as infrared diodes (Bettega et al., 1996, 2002) or ultrasonography (Gateno et al., 1993); to various instruments that attach the proximal condyle-bearing segment to either osseous or dental fixed distal anchoring sites or to the maxilla (Yagami and Nagumo, 1996; Harada et al., 1997; Joos, 1999). Some clinicians have investigated the feasibility of intraoperative awakening of the patient before fixation of the proximal segment (Politi et al., 2007).

Clinical investigations have shown a high incidence (40–85%) of neurosensory deficits associated with BSSO (MacIntosh, 1981; Nishioka et al., 1987; Westermark et al., 1998). Possible causes include traction on the inferior alveolar nerve (IAN) during operation, direct injury to the nerve when the ramus is split or the screw holes are drilled, and compression of the bony segments on the IAN as a result of rigid fixation.

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One study reported a 13% increase in the incidence of subjective sensory changes when screws were used for fixation compared to MMF after BSSOs (Bouwman et al., 1995). Other authors reported more abnormalities of evoked potentials and pathological neuronal changes when bicortical screws were used compared to monocortical screws and miniplate fixation in monkeys (Hu et al., 2007).

Emphasizing the negative effect of nerve compression, some authors continuously recorded orthodromic sensory nerve action potentials (SNAPs) of the IAN in 20 patients with mandibular retrognathia during BSSO (Teerijoki-Oksa et al., 2002). Despite using positional screws and no visible damage to the nerve during splitting, the SNAP disappeared in four cases during fixation and upon tightening of the screws. In accordance with the above findings, another study retrospectively reviewed 68 patients (136 sites) who had a BSSO for mandibular advancement and were fixed using either wires, bicortical lag screws or monocortical mini-plates (Nesari et al., 2005). Of the sites that received lag screws, 34% showed neurosensory affection compared to only 15% of the sites that received monocortical plates at 2.5 years. The authors suggested that compression of the nerve during fixation is one major reason for nerve dysfunction and that with bicortical screws, injury to the inferior alveolar nerve can occur during drilling or screw placement.

With the increasing popularity of computer-assisted orthognathic surgery, great interest has been shown in developing techniques to transfer the virtual plan into the operating room using either dynamic navigation techniques (Bell, 2011) or with the aid of various positioning wafers and templates (Metzger et al., 2008; Bai et al., 2010, 2012; Shehab et al., 2013). There are only two reports on the use of tooth-borne computer-generated CPDs for BSSO (Zinser et al., 2012; Polley and Figueroa, 2013).

In this study we aimed at investigating the use of a bone-borne computer-generated stent for maintaining the condylar position and minimizing IAN injury during BSSO.

2. Material and methods

2.1. Patient selection

Patients were selected from the pool of patients presenting to the departments of orthodontics and oral and maxillofacial surgery at Cairo University with a skeletal class II or III malocclusion that required isolated mandibular orthognathic surgery.

Clinical examination of the patients included assessment of facial symmetry and proportions, occlusal relationship and temporomandibular joint function.

2.2. Preoperative planning

Where necessary, patients received orthodontic preparation, occlusal appliances to alleviate TMD at least 4 weeks prior to surgery and/or occlusal wafers to guide the condyles in their centric relation if it did not coincide with the maximum intercuspation position. Maxillary and mandibular impressions were taken using a polyvinyl siloxane impression material and casts poured in extra-hard stone. The casts were then mounted on a simple hinge articulator in the final desired occlusion.

Preoperative radiographic records of the patients consisted of a computed tomographic (CT) scan of the mandible acquired using a cone beam CT scanner. The image acquisition parameters were as follows: voxel size = 0.3 mm, extended field of view (FOV) = 17 × 23 cm, 120 KV, 5 mA and an exposure time of 4. The maxillary and mandibular casts; in final occlusion; were then CBCT scanned according to the following protocol: FOV = 8 × 8 cm and a voxel size of 0.125 mm. All images were acquired in a digital DICOM format.

The patients' CBCTs were imported into surgical planning software (Mimics 10.0: Materialise, Leuven, Belgium). A segmentation process was then carried out to select only the bony structures out of it and calculate a 3D model. Virtual anatomic Frankfurt and Mid-sagittal planes were constructed and the 3D model aligned accordingly. The artifact dentition was separated from the skull model and replaced with the 3D model of the scanned casts. The maxillary cast was registered to the maxillary CT dentition using a markerless iterative closest point (ICP) registration method with a minimum of 6 artifact-free dental landmarks identified on both the 2D and 3D views (Fig. 1). The same was repeated for the mandibular dentition. An artifact-free composite skull/dentition model was then achieved.

The medial, vertical (anterior) and connecting cuts were then simulated on each side of the 3D mandible to complete a virtual BSSO. The right and left inferior alveolar nerves were then segmented and their 3D paths generated.

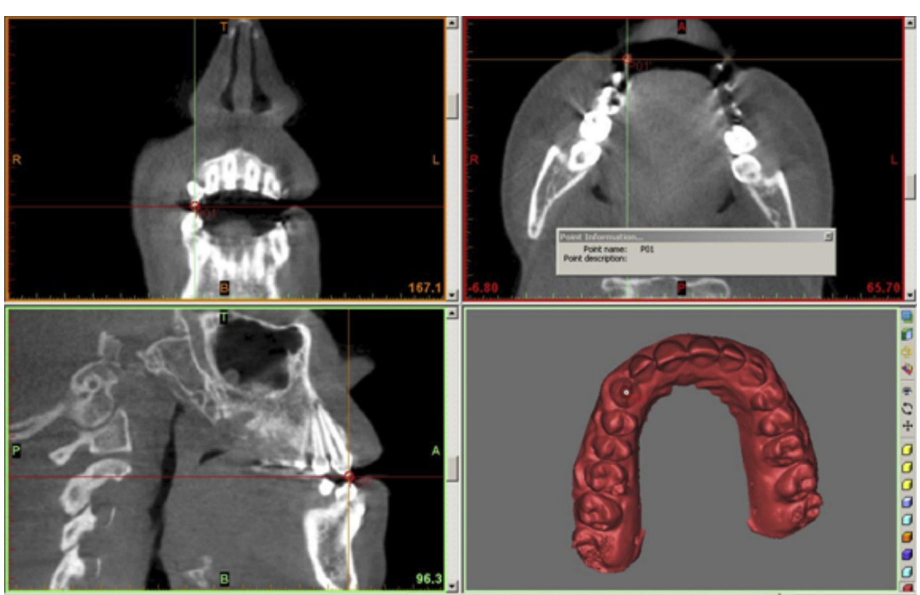

Fig. 1. Point-based registration of the maxillary cast dentition to artifact-free dental landmarks of the CBCT in the axial, coronal and sagittal views.