Use of Kinesiography to Assess Mandibular Function Following Segmental Resection and Microvascular Reconstruction

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Abstract: Mandibular reconstruction has attained adequate morphological outcomes. However, some patients encounter difficulties in oral function and limited mandibular movements. An objective: evaluation has seldom featured actual kinetic measurements after mandibular reconstruction.

Thirty patients who underwent mandibular reconstruction using bony free flap were enrolled in the study. Twenty-two patients were recruited after surgery and compared to a control group of 8 healthy subjects; 8 patients underwent both pre and postoperative evaluations. For each patient, a kinesiographic scan was obtained, recording maximum mouth opening, maximal laterality, and maximal protrusion.

All postoperative kinesiographic evaluations were performed at least 6 months after surgery to ensure complete healing. In the first group of 22 patients, all measured movements were less than those of healthy controls, in particular maximum mouth opening. In the second study group (pre and postoperative evaluation), the postsurgical values did not achieve the control ones, but were no less than the preoperative values, granting adequate functional outcomes.

The kinesiograph appears useful for objectively recording the functional outcomes in patients who have undergone mandibular reconstruction. The postoperative jaw movements were acceptable, ensuring a sufficient functional recovery.

Key Words: Fibula free flap, head and neck reconstruction, kinesiography, mandibular kinesiograph, mandibular reconstruction

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In the field of maxillofacial surgery, mandibular reconstruction after oncological resection is challenging. Since the introduction of a vascularized free fibular flap by Hidalgo in 1989,[1] use of this flap has become the technique of choice.[2] The flap can be shaped via multiple osteotomies to reproduce the native jawbone,[3,4] allowing wide bone reconstruction and attainment of optimal aesthetic results.[5,6] Computer-assisted surgery can help surgeon to improve clinical outcomes.[7,8] However, some patients encounter difficulties after ablative reconstructive surgery using a free fibular flap. Oral functions (speech, swallowing, chewing, and the ability to take a variety of food) have major impacts on patients' perceptions of outcomes.[9] Several studies have found that although facial appearance may be satisfactory, issues arise with speech, food tolerance, and deglutition.[10] However, those studies featured clinical examinations and the use of specific questionnaires such as the Jaw Function Limitation Scale (JFLS).[11] In addition, mandibular reconstruction may cause muscular imbalance, asymmetrical limited mandibular motion,[12] and reduced maximum mouth-opening.[13] Objective evaluation has seldom featured actual kinetic measurements after mandibular reconstruction. We are the first to employ a mandibular kinesiograph to this end. The device was created by Jankelson in 1969[14] and is used to obtain pre and postoperative data in the field of orthognathic surgery.[15] The device accurately registers mandibular movements while a patient engages in mouth-opening and left/right movements of the jawbone, among other movements. The device accurately (to 0.1 mm) displays all mandibular movements on the vertical, anteroposterior, and lateral axes.[16] Interference with natural jaw movement is minimal and measurements are repeatable and reproducible,[17] and thus operators quickly become proficient.

The main aim of this study was to assess the feasibility of this evaluation method, using mandibular kinesiograph, in this type of patients. We then explored how kinesiographic parameters and mandibular movements changed after bone resection and reconstruction. The data could highlight areas that are particularly crucial in terms of mandibular function, allowing the physician to explain the expected functional outcomes to the patient, and guiding treatment seeking to optimize outcomes.

MATERIALS AND METHODS

The study was approved by the S. Orsola Hospital Ethics Committee in September 2017 (approval no. 218/2017/O/Sper) as an: "Interventional Study without drug use, exploratory, with a control group."

We included 30 patients who underwent reconstructive mandibular surgery from December 2010 to May 2018 at the Department of Maxillofacial Surgery at Policlinico S. Orsola-Malpighi, Bologna.

The inclusion criteria were malignant or benign mandibular lesions; segmental mandibular resection and reconstructive surgery using a free microvascular flap; good general clinical condition; and both clinical and functional stability.

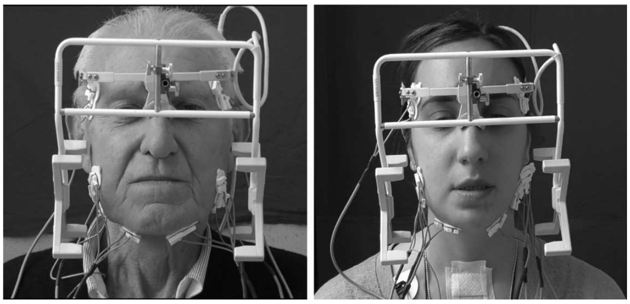

FIGURE 1. Kinesiographic parameters were recorded using mandibular Kinesiograph (K7 Evaluation System).

All patients were informed about the research project and all adults gave written informed consent. Minors expressed verbal agreement and the consent forms were signed by their parents. The patients were divided into 2 groups.

Twenty-two patients (14 males and 8 females; average age 49 years old; range 8–83 years) were recruited after surgery (Supplementary Digital Content, Table 1, http://links.lww.com/SCS/B573) and were stratified based on their mandibular defects using our specific reconstructive algorithm.[18]

The data were compared to those obtained from a control group of 8 healthy subjects (4 males and 4 females; average age 56 years old; range 24–73 years) without oral cavity disease or orthodontic or temporomandibular joint problems.

A second group, consisting of eight patients, underwent both pre and postoperative evaluations (Supplementary Digital Content, Table 2, http://links.lww.com/SCS/B573).

All kinesiographic measurements were noninvasive and thus did not cause any pain or discomfort.

All measurements were made using a mandibular kinesiograph (K7 Evaluation System, Myotronics Research Inc) (Fig. 1), which records mandibular movements in 3 dimensions.

First, a small magnet (3×6 mm) was placed on the vestibular mucosa (the labial surface of the lower incisor midline) using removable adhesive (Stomahesive; ConvaTec Inc, Deeside, UK); the small incision on the magnet was to the right of the examiner. We ensured that the magnet did not interfere with occlusion. The patient donned a goggles-type frame bearing 2 sensor arrays (each sensor was a small conductive coil); the upper bar of the frame was parallel to the eyes and the side bars were parallel to the Frankfort horizontal plane. Magnet motion affected sensor currents; the changes were digitized and used to reconstruct the position of the magnet (and therefore the jaw) in space and time. Before each examination, the patient was asked to relax, and to sit upright with the head unsupported in a quiet room in our clinic. The examiner (who received training by the manufacturer of the device) explained the required movements and waited a few minutes prior to commencement. First, the subject maximally opened and closed the mouth, and then moved the jaw from the point of maximum intercuspation to as far right and left as possible, with sliding on the teeth, if present. Then the jaw was extended as far forward as possible and returned to the starting position. For each patient, a scan was obtained, recording all mandibular movements in the frontal, anteroposterior, and lateral planes (Fig. 2). Maximum mouth opening, maximal laterality (the mean of the right and left lateralities), and maximal protrusion were recorded (in mm); all controls were similarly analyzed.

Stored digitized data were then evaluated by other examiners who were not blinded to patient clinical data. We calculated means with standard deviations and compared patients and controls and the pre and postoperative data.

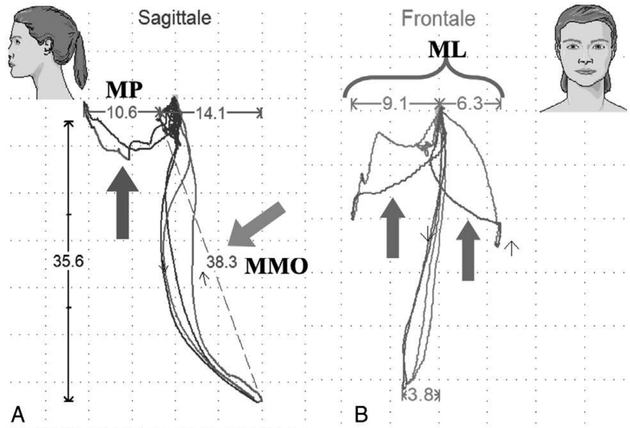

FIGURE 2. Kinesiographic evaluation: mandibular movements in the anteroposterior plane with Maximum Mouth Opening (MMO) with green arrow and Maximal Protrusion (MP) with blue arrow (A). Mandibular movements in frontal plane with Maximum Laterality (ML) with red arrows (B).

RESULTS

All postoperative tests were performed at least 6 months after surgery to ensure that healing was complete. Of the 22 test patients, 11 had undergone adjuvant radiotherapy (Supplementary Digital Content, Table 3, http://links.lww.com/SCS/B573). Data obtained from this first study group were compared to healthy subjects (Supplementary Digital Content, Table 4, http://links.lww.com/SCS/B573).

In the control group, the mean maximum mouth opening (the extent of jaw travel from the centric occlusion [the position of maximum dental arch intercuspation] to the point of maximum opening) was 48 mm (standard deviation [SD] $\pm$ 10.68 mm). The mean maximal laterality was 9.3 mm (SD $\pm$ 1.56 mm) and the mean maximal protrusion was 8.3 mm (SD $\pm$ 3.90 mm).

In the study group (resected and reconstructed patients), the respective values were 36 (SD $\pm$ 12.34), 6.5 (SD $\pm$ 2.23), and 6 (SD $\pm$ 2.75 mm). The patients were stratified by mandibular defect type as follows: Type I (lateral defect), Type Ic (lateral defect involving the condyle), Type II (anterior defect), and Type III (subtotal defect).

In patients with lateral defects, the mean maximum mouth opening was 34 mm (SD $\pm$ 10.75 mm), thus 14 mm less than controls. The mean maximal laterality was 6.7 mm (SD $\pm$ 1.77 mm), 2.6 mm less than controls. The maximal protrusion was 6.8 mm (SD $\pm$ 1.77 mm), 1.5 mm less than controls. In patients with Type Ic defects, the figures were 24 ($\pm$14.70), 3.1 ($\pm$1.35), and 3.5 ($\pm$2.70), respectively (*see* Supplementary Digital Content, Table 5, http://links.lww.com/SCS/B573 *for differences versus controls*). In patients with anterior defects, they were 41 ($\pm$11.75), 8 ($\pm$1.93), and 6.5 ($\pm$3.40), respectively. In patients with subtotal defects, they were 46 ($\pm$8.20), 6.1 ($\pm$2.32), and 4.6 ($\pm$2.61), respectively (*see* Supplementary Digital Content, Table 6, http://links.lww.com/SCS/B573 *for differences versus controls*).

In the second study group (pre and postoperative evaluation), the mean kinesiographic values were compared. The mean pre and postoperative maximum mouth openings were both 32.2 (SD $\pm$ 17.34) and 32.2 ($\pm$6.24 mm). The respective maximal lateralities were 6.5 ($\pm$2.4) and 8.4 ($\pm$2.65) and the maximal protrusions were 4.5 (±3.28) and 4 (±2.21) (Supplementary Digital Content, Table 7, http://links.lww.com/SCS/B573).

DISCUSSION

After the complete removal of oral cancer, a good quality of life can be assured via immediate reconstruction of the mandibular profile using bones or composite free flaps[19,20] with a focus on both function and aesthetics. Many studies have evaluated patient satisfaction and possible problems with speech, swallowing, chewing, and adequate nutrition[21]; asymmetrical/limited mandibular movement; and reductions in mandibular motion. However, in those studies, outcomes were evaluated via clinical examination and questionnaires.[22] No prior study has objectively evaluated mandibular function in terms of kinetic outcomes after reconstruction. Despite the importance of such work, no protocol exists. A mandibular kinesiograph was used, traditionally employed by orthognathic surgeons,[10] to evaluate the patients involved in the study. It was first determined that the device was practicable and then gathered kinetic data.

Only 5 prior studies have assessed mandibular movement after reconstructive surgery, one of which used a mandibular kinesiograph, but to a different end, exploring how dental implants improve mandibular function after mandibular reconstruction. That study found that mandibular movement of an implant-supported prosthesis was not compromised.[23]

The other 4 studies did not use kinesiography; one employed a digital device to measure movements of 2 cutaneous points,[24] one used 4-dimensional computed tomography,[25] one employed an ultrasonic axiograph[26] and the final work utilized an optoelectronic digitizer.[27]

Therefore, the use of a kinesiograph to evaluate the mandibular kinetics of 30 patients is novel. The technique is repeatable and reproducible, associated with minimal interference with jaw movements by the frame and small magnet, and exhibits a relatively narrow learning curve.[11]

Thirty patients have been divided into 2 groups. The first 22 were examined after surgery only and it was explored whether the suggested approach was practicable. It was found as follows: the postsurgical status of the oral cavity did not impose any limitations. All measured movements were less than those of healthy controls, particularly maximum mouth opening (36 versus 48 mm), attributable to the surgical intervention. Bone resection, and muscle dissection in particular, causes scarring, which is increased in some patients by postoperative irradiation associated with postactinic fibrosis[28] that replaces mandibular muscles such as the masseter and the pterygoid muscles that are often involved in surgery (and sometimes sacrificed during surgery). This inelastic fibrotic tissue that replaces muscles reduces mucosal stretching and elasticity,[17] limiting lateral movement, protrusion, and mouth-opening. However, such movements remain possible after surgery, ensuring an acceptable residual function.

The study population was divided accordingly the type of mandibular defect (Supplementary Digital Content, Tables 5, http://links.lww.com/SCS/B573 and 6, http://links.lww.com/SCS/B573). Lateral defects (Type I), particularly those involving the condyle (Type Ic), greatly affected mandibular kinetics (maximum mouth opening was halved in those with Type Ic defects). *Wetzels* considered that, in such patients, the closeness of posterior tumors to the masseter and pterygoid muscles might be associated with more tumor- and/or treatment-associated muscle damage up to the region of the temporomandibular joint.[21] Therefore, it is important to insert the muscles, if detached, into the most anatomically correct positions, particularly in patients with Type I and Ic defects, to minimize constraints on mandibular movement.[29]

Differently, patients with anterior defects were less affected.

In the second study group, both pre and postoperative functional impairments were assessed; therefore, the kinetic impacts of surgery were then explored (Figs. 3 and 4). Please note that pathologies

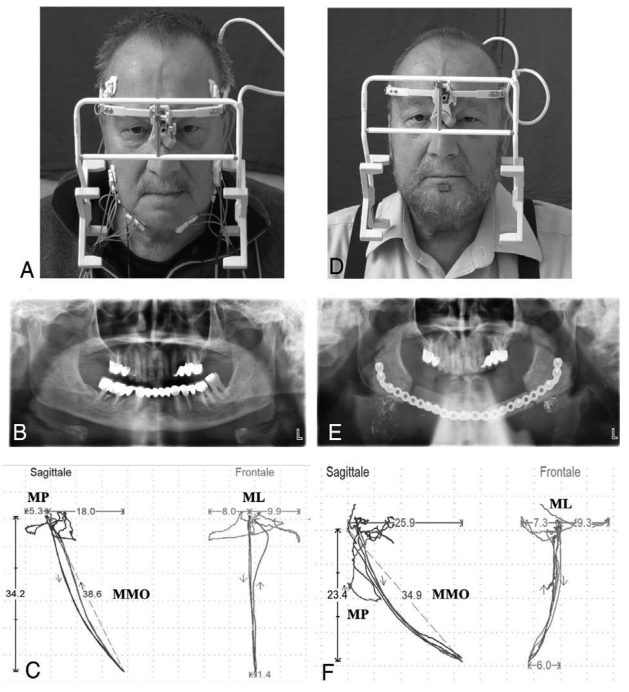

FIGURE 3. Second study group was evaluated pre and postsurgery. Patient affected by osteonecrosis involving mandibular symphysis and body. On the left, preoperative frontal view (A) and preoperative panoramic radiograph (B). Below, preoperative functional evaluation: Maximum Mouth Opening (MMO), Maximal Laterality (ML), and Maximal Protrusion (MP) (C). On the right, postoperative frontal view (D) and postoperative panoramic radiograph (E). Below, postoperative functional evaluation (F).

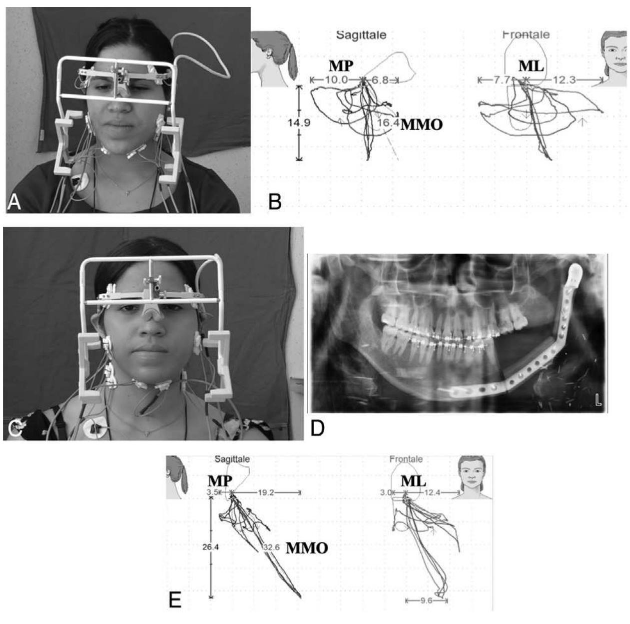

FIGURE 4. Patient affected by Garrè sclerosing osteomyelitis of the left ramus involving the condyle. (Above) Preoperative kinesiographic evaluation (A) and kinesiographic scan with Maximum Mouth Opening (MMO), Maximal Laterality (ML), and Maximal Protrusion (MP) recording (B). (Below) Postoperative functional evaluation (C), panoramic radiograph, with fibular free flap and a titanium plate with a custom-made titanium condyle (D). Postoperative kinesiographic scan (E).

were evident even preoperatively (compared to controls), explained by limitations imposed by pain and the fear of performing movements that cause pain.[30] Surgery barely affected maximum mouth opening or maximal protrusion. Thus, the postsurgical values did not attain those of controls, but were no less than the preoperative values, thus affording adequate functional outcomes. The postoperative improvement in maximal laterality may reflect the fact that the existing (preresection) disease compromised the functions of the lateral and anterolateral mandibular bones and muscles, either by imposing a physical obstacle or by increasing inflammation and muscular pain.

Even if the number of investigated patients was law, the study results suggest, however, that a clear trend in outcomes is apparent. Further work with more patients is required.

The results seem encouraging: the kinesiograph appears a suitable tool to objectively register the functional outcomes in patient who have undergone mandibular reconstruction.

Study results underlined that the residual postoperative jaw movements were acceptable, ensuring an adequate functional recovery in relation to the bone resection and reconstruction.

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