Lim K. Cheung, BDS, PhD, FFDRCS, FDSRCPS, FRACDS, FRACDS, FHKAM, FCDSHK, FDSRCS
Professor

John Lo, BDS, MDS, MOS, RCS
Honorary Clinical Assistant Professor

Oral and Maxillofacial Surgery
Faculty of Dentistry
The University of Hong Kong

Reprint requests:
Dr L. K. Cheung
Oral and Maxillofacial Surgery
Faculty of Dentistry
University of Hong Kong
2/F, Prince Philip Dental Hospital
34 Hospital Road, Hong Kong SAR
Fax: +852-2559-9014

The long-term clinical morbidity of mandibular step osteotomy

The objectives of this retrospective study were to assess the clinical applications of mandibular step osteotomy (MSO) and to evaluate its long-term clinical morbidities. A total of 152 patients with MSO performed between 1990 and 1999 were assessed. Forty-two patients were successfully recalled through questionnaires and clinical parameters for clinical evaluation, which included (1) tooth sensibility; (2) periodontal status; (3) neurosensory deficit in terms of light-touch threshold, 2-point discrimination, and pain threshold; and (4) temporomandibular joint function. The patients were finally asked about their overall satisfaction with the surgical treatment. The result revealed that MSO was commonly indicated for the correction of mandibular hyperplasia. Clinical assessments showed that 2.75% of the teeth assessed had negative pulpal response, 3.9% showed mildly increased probing depth, and another 3.9% showed gingival recession. Neurosensory assessment revealed that 31% of the operating sites had an increased light-touch threshold, 4.8% had heightened 2-point discrimination, and 9% had an elevated pain threshold. Also, 9.7% of the patients showed reduced mouth opening and 17% had mild tenderness of masticatory muscles. Of all the patients assessed, 12% were not satisfied with the orthognathic treatment. The reasons included relapse, residual asymmetry, and persistent paresthesia. (Int J Adult Orthod Orthognath Surg 2002;17:283–290)

Mandibular step osteotomy (MSO) is a mandibular body osteotomy technique that involves a step-cut made anterior to the mental foramen. It is indicated for correction of mandibular hyperplasia by either using the space from extraction of a posterior tooth or by closing an existing edentulous space. MSO is different from ramus osteotomy in that it allows further modification of the dental arch form vertically for closure of anterior open bite or correction of reverse curve of Spee and transversely for arch constriction. The stability of the osteotomy is enhanced mechanically by the step-cut design, which provides a favorable fracture pattern as well as maximal bony approximation. Fixation can be easily achieved by 1 miniplate on each side.

Von Eiselburg first described the MSO technique for correction of mandibular retrognathia in 1906.[1] Shortly after, Pichler (in 1918) described the use of MSO for correction of mandibular prognathism.[2] They both performed the technique through an extraoral route with no intention of preserving the mental nerve. In 1948, Dingman[3] combined the intraoral and extraoral approaches for correction of mandibular retrusion. Converse and Shapiro[4] were the first to perform MSO using a pure intraoral approach. They recommended different step designs for the correction of a variety of mandibular deformities; this included the conventional step-cut for correction of mandibular prognathism and closure of anterior open bite and the reverse step-cut for mandibular advancement. Preservation

Int J Adult Orthod Orthognath Surg Vol. 17, No. 4, 2002

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Fig 1 Mandibular step osteotomy with miniplate fixation.

Table 1 Clinical applications of step osteotomies in 152 patients

Osteotomy type	n	Diagnosis and concomitant osteotomy
Step osteotomy alone	9	Mandibular hyperplasia (6), mandibular asymmetry (3)
Step osteotomy + maxillary osteotomies	105	Le Fort I (88), Le Fort II (6), Wunderer and bilateral Schuchardt (5), Le Fort I and unilateral Schuchardt (5), bilateral Schuchardt (1)
Step osteotomy + maxillary osteotomy + ramus osteotomy	29	Mandibular hyperplasia (22), asymmetry (6), anterior open bite (1)
Miscellaneous conditions	9	Step + Le Fort I + genioplasty (2), step + bone grafting to maxilla (6), step + maxillary distraction (1)

of the mental nerve was achieved by buccal osteotomy under direct exposure and protection of the nerve. Fordyce and Wedgwood[1] presented a clinical series of 30 patients treated by intraoral MSO with wire fixation. The results showed that 10% of the patients experienced bilateral mental paresthesia and 10% had adjacent tooth damage during the osteotomy. Sandor et al[2] confirmed a similar incidence of long-term paresthesia in 9% of the osteotomies they performed; the stability of the osteotomies achieved by maxillomandibular fixation in their group was reported to be 7%. The feasibility of combining MSO with vertical ramus osteotomy was highlighted by Stoelinga and Leenen.[5] The fixation was changed to 1 miniplate on each side of the mandible.

The aims of the present study were *(1)* to assess the clinical applications of MSO in Hong Kong and *(2)* to retrospectively evaluate the long-term clinical morbidities of MSO, including vitality and periodontal health of the teeth adjacent to the osteotomy, neurosensory recovery in the mental region, and temporomandibular joint (TMJ) function.

Materials and methods

One hundred fifty-two patients had MSO performed in the Department of Oral and Maxillofacial Surgery, The University of Hong Kong, between 1990 and 1999. Their records were checked for skeletal diagnosis, surgical treatment planning, and postoperative complications. The surgical technique of MSO employed was essentially the same as reported by Sandor et al,[2] except that the fixation was by arch bar and 1 miniplate on the lower vertical osteotomy of the step bilaterally (Fig 1). The skeletal diagnoses of this patient group and the types of osteotomy performed are summarized in Table 1. Forty-two patients consented to return for the clinical evaluation and formed the sample of the clinical morbidity study. The criteria for assessment included the following.

- *Periodontal assessment.* Tooth loss resulting from periodontal disease or the need for advanced periodontal therapy such as root planing or periodontal surgery following MSO was recorded. Oral hygiene status, gingival recession, probing depth, and bleeding on probing were charted by a periodontal probe (William 14W, Dentsply International). Probing depth was graded as abnormal if the measurement was greater than 3 mm. Periapical radiographs were taken for the evaluation of bone loss around the teeth that had demonstrated abnormal probing depth.
- *Tooth vitality assessment.* Patients with any root canal therapy done after osteotomy were recorded. Tooth vitality was determined by *(1)* electric pulp tester (Model 2006 vitality scanner, Analytic Technology) and *(2)* cold test (ethyl chloride spray). Teeth responding negatively to both electric pulp and cold tests were considered as nonvital. Periapical radiographs were taken to determine any periapical changes of the affected teeth.

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- *Neurosensory assessment.* Patients were asked about any neurosensory symptoms following the osteotomy and their duration. The affected areas localized by the patients were recorded. Three methods were employed for the assessment of sensory nerve function: *(1)* light-touch threshold was assessed by an ascending sequence of von Frey monofilaments (Research Design); *(2)* 2-point discrimination was assessed by a custom-made plastic disc that incorporated 10 pairs of blunt stainless steel wire probes with separation from 2 to 20 mm mounted at 2-mm ascending intervals; and *(3)* pain threshold, which was tested with a 23-gauge needle attached to the arm of an orthodontic gauge meter.
- *TMJ assessment.* Symptoms of pain or clicking were recorded according to their severity and frequency. When a symptom was present, the onset, particularly if it commenced after the osteotomy or if there was any report of improvement after the osteotomy, was recorded. Painful symptoms were scored on a sliding scale, from 0 (symptom-free) to 10 (severe and affecting the quality of life). Joint mobility and masticatory muscle status were assessed. The range of movement measured consisted of both vertical mouth opening (interincisal distance) and lateral excursion to both sides from the dental midline. The masticatory muscles examined included the masseter, temporalis, and lateral pterygoid muscles. Tenderness on palpation of any specific muscle group was recorded.
- *Patient satisfaction.* Patients were asked to grade their overall satisfaction with the surgical treatment. Satisfactory was defined as the patient's willingness to accept the same surgical treatment if given a second chance to consider the osteotomy. For patients who were not satisfied with the surgical treatment, the reasons for their dissatisfaction were recorded.
- *Radiographic assessment.* Panoramic radiographs were used to assess any gross apical pathology or endodontic treatment performed. Periapical radiographs were taken to define any pathology noted. Mandibular condylar morphology from follow-up radiographs was compared to that of the preoperative radiographs for the assessment of remodeling.

Owing to a lack of data regarding preoperative neurosensory and TMJ status, an additional analysis was conducted on a group of normal patients attending our clinic to provide a better comparison with our study group. The readings were compared with the study sample as well as the normative readings recommended from the literature. The control group consisted of 40 patients who came to the clinic for consultation regarding third molars or orthognathic assessment and were free from any TMJ symptoms. Their age ranged from 16 to 44 years (mean, 25 years). The same objective neurosensory and TMJ assessments were performed bilaterally (80 sites).

Furthermore, the data from the neurosensory assessment of the surgical group were also compared with the normative values and the upper limit obtained from the studies of Campbell et al[6] and Zuniga and Essick.[7]

The differences in neurosensory results between the study and the control groups were compared graphically, while the differences between the ranges of joint movements were analyzed. Unpaired *t* tests were performed by using GraphPad InStat (version 3.00 for Windows 95, GraphPad Software).

Results

Between 1990 and 1999, a total of 152 patients received MSO (86 women and 66 men). The age ranged from 13 to 53 years (mean age 23.9 years). The majority of patients (78.3%) presented with a skeletal diagnosis of mandibular hyperplasia, either alone (12.5%) or combined with maxillary deformities (65.8%), such as maxillary hypoplasia or posterior vertical maxillary excess; 9.6% of patients presented with mandibular asymmetry and 6.5% of patients presented with anterior open bite. MSO was rarely performed alone (5.3%). In the majority of cases (71.7%), MSO was performed concurrently with maxillary osteotomies. MSO was occasionally performed simultaneously with additional mandibular ramus osteotomies (20%). On

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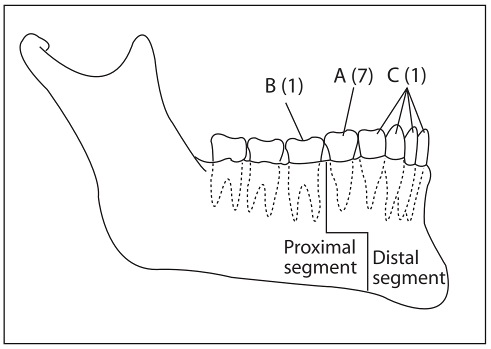

Fig 2 Distribution of the teeth with double-negative vitality tests. Group A = teeth in the distal segment and adjacent to the osteotomy site; group B = teeth in the proximal segment and adjacent to the osteotomy site; group C = teeth in the distal segment but not adjacent to the osteotomy site.

rare occasions, MSO was performed in combination with genioplasty (2.6%), forming a mandibuloplasty procedure (Table 1).

Forty-two patients (27 women and 15 men) were successfully recalled for the clinical evaluation. The age at operation ranged from 13 to 43. A total of 84 osteotomy sites and 420 teeth were examined.

No postoperative complications were reported, such as infection, dehiscence, or exposed fixation plates. None of the patients received extraction or advanced periodontal therapy after the osteotomies. Four teeth (in 3 patients) received endodontic treatment after the osteotomies, accounting for 0.98% of the total number of teeth examined. All endodontically treated teeth were adjacent to the osteotomy sites, and the apical pathologic changes were noted after surgery. Among these teeth, 1 showed obvious signs of traumatic damage on its root. On average, patients showed reasonable oral hygiene, with the average plaque score below 1. Eleven patients showed increased probing depth (4 to 5 mm) in 16 teeth, with 6 teeth (37.5%) adjacent to the osteotomy sites. Generalized recession (within 1 to 3 mm) was noted in 15 teeth.

No tooth discoloration was noted, except in 1 tooth with a history of endodontic treatment. A total of 211 teeth (in 21 patients) showed positive response to both vitality tests; 19 teeth (in 8 patients) responded negatively to electric pulp tests, and 43 teeth (in 16 patients) responded negatively to cold tests. Vitality tests could not be performed in 2 teeth; one had a root canal treated–molar and the other had multiple crowns before the surgery. One patient revealed an incidental finding of external root resorption in 1 tooth adjacent to the osteotomy site during the assessment, and endodontic treatment was arranged subsequently. When both the electric pulp test and cold test results were taken into account, 9 teeth showed double-negative responses, which contributed to only about 2.1% of the teeth examined. Among them, 8 teeth were immediately adjacent to the osteotomy sites (Fig 2).

The majority of patients (61%) reported subjective sensory recovery of the mental regions within 3 months. One patient had the mental nerve torn during surgery, and immediate anastomosis was performed; full sensory recovery was demonstrated within 1 year. Fewer than 20% of the patients reported hypoesthesia after 1 year of operation. Five patients (12%) reported persistent, long-term paresthesia (postoperative periods ranged from 5.5 to 8.5 years). Among these patients, 2 noted disturbance on the left chin region including the lower lip, and 1 noted disturbance on the left side of the lower lip only.

Regarding the light-touch threshold, the majority of the surgical sites (82%) were sensitive to small fibers (below 2.36 von Frey fiber size) (Fig 3a). For the control group, the values ranged from 1.65 to 2.44 von Frey fiber size (Fig 3a). Using the normative values and upper limit obtained from Campbell et al[6] and Zuniga and Essick,[7] respectively, there were three (7.1%) patients with three (3.5%) operative sites that had light-touch perception beyond the upper limit of the normal range. These 3 patients subjectively felt persistent paresthesia after the operation as well.

On 2-point discrimination, most (98%) of the operative sites were responsive to a value of less than 14 mm (Fig 3b). Two patients (2 operative sites) had a 2-point discrimination result located at the upper limit (18 mm) of the normal range. In the control group, all patients responded within an area ranging from 2 to 12 mm (Fig 3b).

The pain threshold of the majority (87%) of surgical sites was below 40 g pressure,

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Fig 3a Neurosensory comparison of light-touch threshold of the surgical and control groups in the mental region. The manufacturer marking (mm) represents the logarithm of 10 times the force in milligrams required to bow the monofilaments.

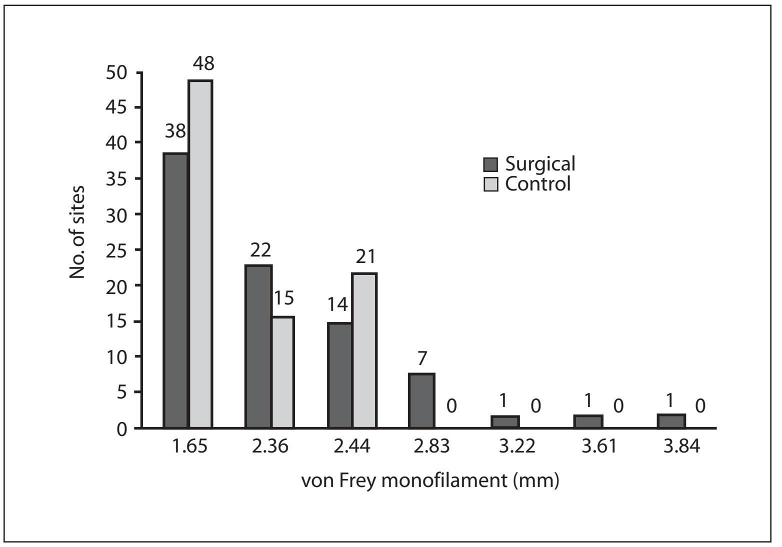

Fig 3b Neurosensory comparison of 2-point discrimination of the surgical and control groups in the mental region.

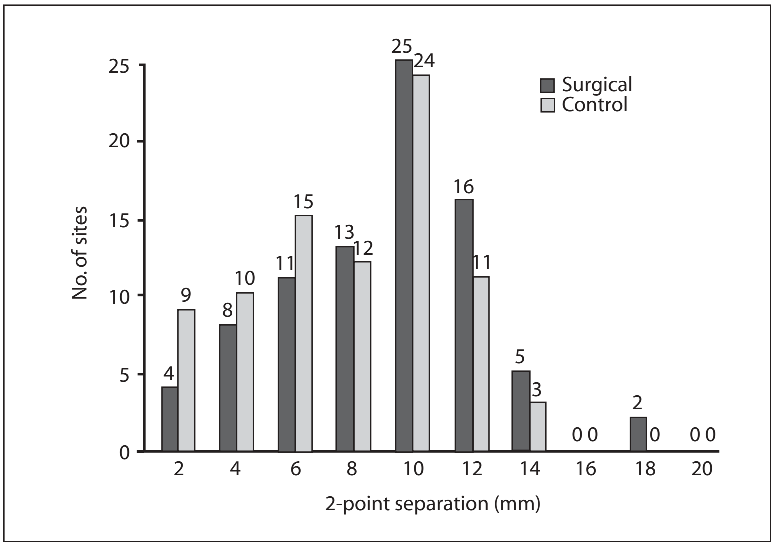

Fig 3c Neurosensory comparison of pain threshold of the surgical and control groups in the mental region.

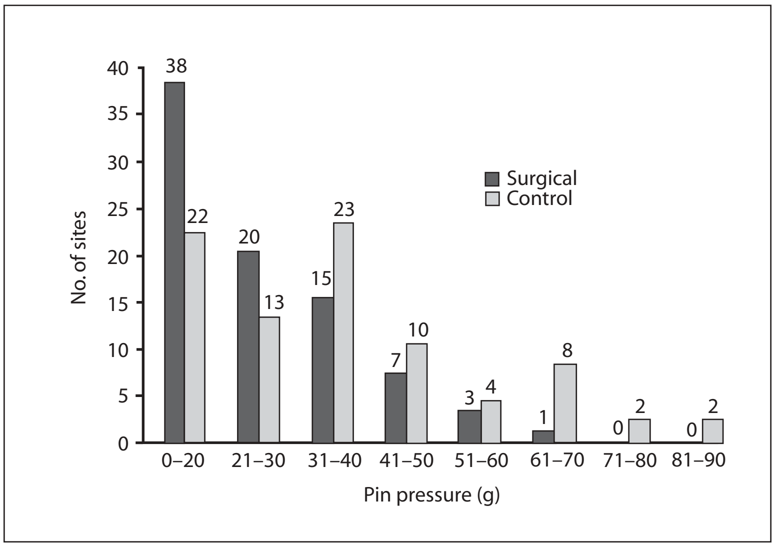

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Table 2 Summary of the neurosensory status of the mental region in the surgical group (n = 84) in comparison to control group and other studied groups[6,7]

Test	No. (%) of sites outside normal range[6]	No. (%) of sites beyond upper limit of normal[7]	No. (%) of sites beyond upper value of control group
Light-touch threshold	24 (28.57%)	3 (3.66%)	10 (11.90%)
2-point discrimination	7 (8.33%)	0	7 (8.33%)
Pain threshold	26 (30.95%)	N/A	0

Table 3 Comparison of TMJ movement in the surgical group (n = 42) and the control group (n = 40)

	Vertical opening (mm)		Lateral excursion (mm)		
Group	Mean ± SD	Range	Right side	Left side	Range
Surgical	44.548 ± 7.259	30–63	6.56 ± 2.07	6.74 ± 1.97	2–11
Control	44.929 ± 5.348	35–55	8.59 ± 2.80	8.42 ± 2.75	3–14

with the largest reading extending to 70 g (Fig 3c). In the control group, 92% of the subjects had pain threshold below 40 g, and the largest reading reached 86 g (Fig 3c).

The neurosensory status of the mental nerve distribution following mandibular step osteotomies, in comparison to previously published studies[3,7] and the control group, is summarized in Table 2.

The TMJ assessment revealed 4 patients with occasional pain and 12 patients with occasional clicking, including 2 with clicking noted postoperatively. Nevertheless, all patients claimed that these symptoms caused no disturbance in their social life.

The results of mouth opening and lateral excursions of patients in both the study and control groups are summarized in Table 3. There was no significant difference in the mean vertical mouth opening (unpaired *t* test, $P = .31$). On lateral excursion, there was a significant difference between the surgical and control groups (unpaired *t* test, $P < .0001$). On examination of the masticatory muscles, tenderness was noted in 7 patients. Three patients presented with bilateral masticatory muscle tenderness. The masseter muscle was involved in all cases, while lateral pterygoid muscle was additionally involved in 3 patients. No obvious radiographic changes were noted on the condylar surfaces.

Five patients (12%) were not satisfied with the result of their treatment. The reasons included relapse in 3 patients, residual asymmetry in 1 patient, and persistent numbness after the operation in 1 patient. Only 1 unsatisfied patient received a second operation to correct the residual asymmetry. The remaining 4 accepted the compromised facial profile, occlusion, or altered sensation and were not willing to undergo further surgical correction.

Discussion

Class III facial profile, whether resulting from mandibular hyperplasia, maxillary hypoplasia, or a combination of both, is common in Asians.[8] In comparison to Caucasian samples, Chinese Class III patients tend to show more severe skeletal disharmony, including an increase in mandibular length, a larger posterior cranial base, and a smaller gonial angle.[9] MSO and vertical subsigmoid osteotomy (VSSO) are the most common treatment alternatives for mandibular setback in our clinic. Sagittal split osteotomy is employed less frequently for setback since it is less stable[10] in the correction of mandibular prognathism and carries a higher risk of nerve disturbance versus VSSO.

In those Class III patients who exhibit a hypoplastic maxilla, it is not uncommon for

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some patients to have the maxillary premolars extracted to resolve the dental crowding. MSO with extraction of premolars could provide a relatively stable occlusion in those patients, whereas VSSO would lead to a pair of non-functional molars. MSO could also allow closure of segments of edentulous space. Also, fixation is achieved by titanium miniplates, whereas VSSO still relies on maxillomandibular fixation. Nevertheless, MSO is a relatively lengthy procedure, as time is required for the trimming of interdental bone and application of fixation. It also carries risks for tissues near the osteotomy site, namely the tooth, periodontium, and mental nerve.

The clinical morbidities of MSO in our study could be considered low. There was no evidence of abnormal bony healing, such as nonunion, fibrous union, or exposure of fixation plates. The overall periodontal problem could be classified as mild, since the maximum probing depth reached only 5 mm. Our results are in general agreement with most studies[11,12] and are better than those of Schultes et al,[13] in which 51 of 74 operative sites of mandibular segmental osteotomies showed osseous defects or missing teeth. The periodontal problems are likely to be related to the care in handling of the soft tissues during the surgery. Our design involves a horizontal incision at a line below the mucogingival junction, with the tissue reflection limited to the buccal surface. Maximal soft tissue attachment at the interdental osteotomy site was therefore able to maximize the vascularity of the involved periodontal sites. Considering the effect on tooth vitality, our study also yielded better results than the study of Sandor et al.[2] The improvement in morbidities in this study could be the result of the refinement of our technique and improvement of the instruments for intraoral surgical access. The distribution of non-responding teeth is similar to other studies,[12,14,15] in which the high-risk group is expected to be related to the teeth adjacent to the osteotomy site of the distal segment.

In this retrospective study, the majority (61%) of the patients noted neurosensory recovery within 3 months. This is in agreement with the findings of Theisen and Guernsey,[16] who suggested that temporary neuropathy was related to the traction on the mental nerve for protection during surgery, rather than damage to the integrity of the nerve. A variety of methods were employed in the assessment of the cutaneous sensation. Five patients (12%) showed persistent paresthesia 2 years after surgery, which could be regarded as permanent. This result is similar to those of other studies.[1,2] The reliability between the objective assessment and the patient's subjective report of neurosensory deficit remains controversial. Patients very often have a subjective feeling of neurosensory disturbance, even though objective evaluation shows normal sensibility.[17] Opposite findings have also been presented, with patients reporting normal neurosensory function despite negative objective findings. In our study, there was only 1 case of this, in which a patient complained of numbness in the lower lip region but tested as normal.

There was no significant difference in the vertical mouth opening between the study and control groups. The mean maximal interincisal movement opening was 44 mm, which was similar to that seen by Cox and Walker.[18] On the other hand, there was a significant statistical difference in the lateral excursion between the study and control groups. This finding could be related to the medial rotational changes of the condyle following the constriction of the proximal segments that is commonly required to achieve continuous dental arch. There were 3 patients with a vertical mouth opening of less than 34 mm, which was considered as the minimal limit for adults. Their mouth openings ranged from 30 to 32 mm. Among them, 2 showed signs of myofascial pain. One patient was symptom-free, but he presented with both vertical and lateral movements below the lower limits of the control group.

The main limitation of this study is the lack of preoperative readings, which forces any comparison of the neurosensory and TMJ status to that between the study and the control group or previous studies. A prospective design would be ideal to investigate the neurosensory recovery and TMJ function in future osteotomy studies.

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The majority of the surgical patients in this study were satisfied with the treatment and would accept the same surgical treatment if given a second chance to consider the therapy. However, some patients expressed that they noticed a change in the frontal appearance from a tapered face to a square face following surgery. In retrospect, the use of a visual analog scale on different aspects of profile and functional changes might have quantified the results better.

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