8 Orthognathic Injuries of the Trigeminal Nerve

Anders Westermark

Correction of cranio-maxillofacial deformity by means of orthognathic surgery includes procedures that may cause impaired sensory nerve function in the facial skin distribution. The most common site for such disturbance is the lower lip and chin area following a sagittal split ramus osteotomy of the mandible. Most often, however, such impaired sensitivity is tolerated well by the patient, but careful preoperative information about the risk of obtaining a neurosensory impairment is of primary importance in patient management. It is generally accepted that inferior alveolar nerve injury is the most common complication of mandibular orthognathic surgery, with immediate neurosensory dysfunction occurring in nearly 100 % of patients and long-term paresthesia occurring to a variable degree.

8.1 Orthognathic Surgery

Orthognathic surgery is directed toward correction of malpositioned jaws, or parts thereof. Orthognathic surgery may be performed as mandibular procedures, maxillary procedures, or combined bimaxillary surgeries. Occasionally, the osteotomies employed in orthognathic surgery are utilized to gain access to tumors or other pathological conditions including vascular access. In the vast majority of cases, however, they are used as elective procedures in order to improve occlusion, masticatory function, and facial esthetics. Also, the vast majority of patients treated with orthognathic surgery are young and healthy individuals. A common age for the operation is in the upper teenage years, and in general, such procedures should be done with a minimum of adverse sequelae. That, however, is not always the case. Since orthognathic surgery was established as a common treatment modality half a century ago, it also has been clear that mandibular osteotomies, more commonly than maxillary cases, may be followed by various degrees of neurosensory disturbances (NSDs).

The inferior alveolar nerve (IAN) distributes sensory function to the lower lip and chin, as well as for the buccal gingiva anterior of the mental foramen. The infraorbital nerve (ION) carries the sensation for the skin of the cheek, side of the nose, upper lip, and the buccal gingiva in the anterior region of the maxilla. The somatosensory function of each of these areas is at risk as a result of orthognathic surgery.

8.2 Mandibular Osteotomies

In the mandible, three osteotomy designs and used most frequently including the vertical ramus osteotomy (VRO), sagittal split ramus osteotomy (SSRO), and genioplasty. It is beyond the scope of

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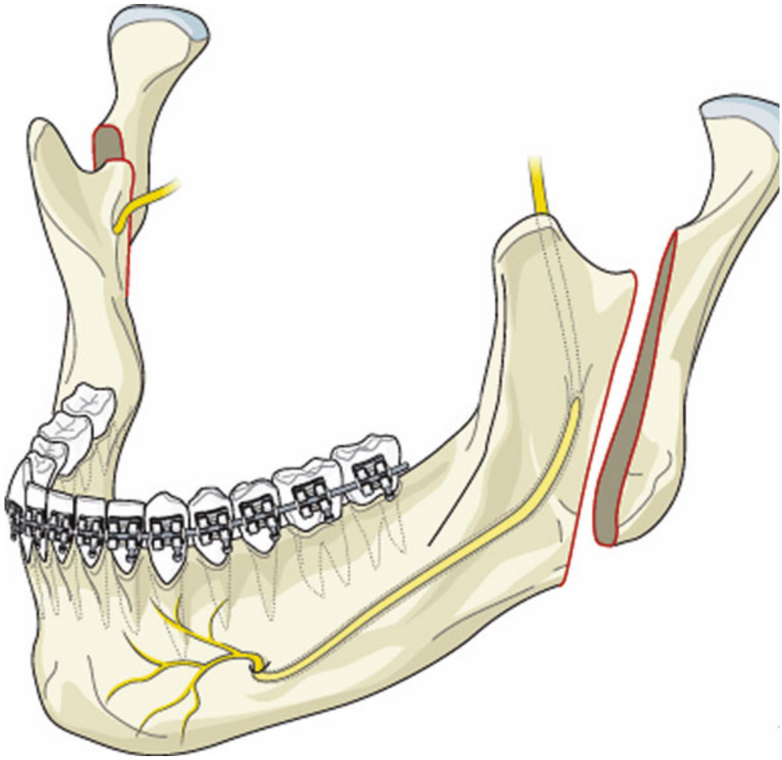

Fig. 8.1 Vertical ramus osteotomy is performed posterior to the mandibular foramen (lingula region) to avoid injury to the IAN

this chapter to describe these surgical procedures in detail, and it is assumed that the there is a familiarity with each of these surgeries.

In short, however, the VRO cuts the mandibular ramus from the sigmoid notch inferiorly to the mandibular angle region (Fig. 8.1). The cut is carried out posterior to where the mandibular nerve enters the mandibular ramus on the medial side in the mandibular foramen at the lingula. In most cases this osteotomy is performed intraorally, but the extraoral approach is also used. The VRO requires intermaxillary fixation (IMF) for 3–6 weeks after surgery if rigid fixation is not utilized. The VRO can only be used for mandibular setback procedures.

The SSRO divides the mandible in the angular region of the ramus and body of the mandible. Between a medial horizontal cut on the ramus and a lateral vertical cut in the molar region, the mandible is split sagitally, ideally along the inner surface of the lateral cortex (Fig. 8.2). This osteotomy can be used for mandibular setback, advancement, and rotational movements. The proximal and distal bone fragments can be fixated with osteosynthesis of various types; therefore, IMF is not needed in the postoperative period. There are many possible risk factors for nerve injury resulting from orthognathic surgery, and these are summarized in Table 8.1.

In the genioplasty procedure, the anterior part of the mandible is cut more or less horizontally below and anterior to the mental foramen, and to a point approximately 1 cm above the symphyseal base (Fig. 8.3). This chin segment of the mandible can then be mobilized and fixated in a new position. In addition, this osteotomy does not disrupt the mandibular continuity.

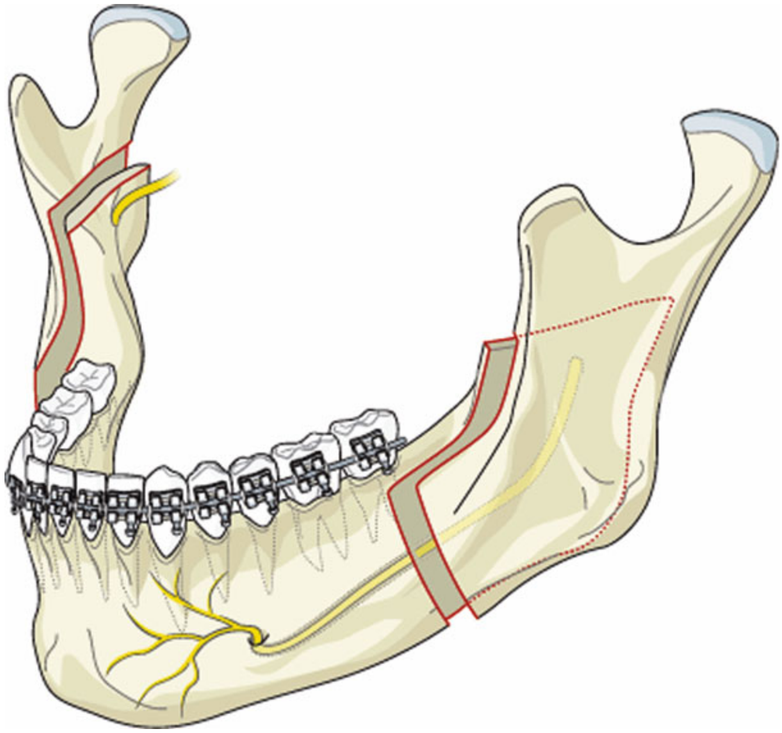

Fig. 8.2 Bilateral sagittal split ramus osteotomy places the IAN at risk for injury due to osteotomy design

Table 8.1 Risk factors for IAN injury during SSRO

Patient age
Patient gender
Type of surgical procedure
Type of mandibular deformity
Variation in nerve anatomy
Surgical technique
Nerve manipulation
Instrumentation
Nerve position (proximal/distal segment)
Method of fixation
Duration of surgery
Surgeon experience
Inadvertent osteotomies (bad splits)
Presence of third molars

Clearly, the SSRO, which splits the mandible along 2–3 cm of the mandibular body and ramus, must be considered as a high-risk procedure for the IAN coursing in the same bony structure, at least much more than the VRO and genioplasty, and this is also reflected in the literature.

8.2.1 Sagittal Split Ramus Osteotomy (SSRO)

One of the pioneers of SSRO, Hugo Obwegeser, discussed in a paper in 1964 [13] the indications for the procedure without even mentioning the risk of NSD as a result of the surgery. Later, numerous papers have indicated that SSRO might be followed by more than a minimal NSD of the lower lip and chin. Of interest is the extremely variable occurrence of NSD after SSRO reported in the literature. In his thesis [20] Westermark made a list of 35 papers published between 1974 and 1999, in which NSD of the lower lip and chin were reported from between zero and 85 % following SSRO surgery. It was not only the reported numbers that varied widely but also the method used to evaluate neurosensory function. Further, some authors reported per side NSD incidence, while others reported per patient incidence. Some authors with very low numbers of NSD performed their evaluation by testing the skin response with

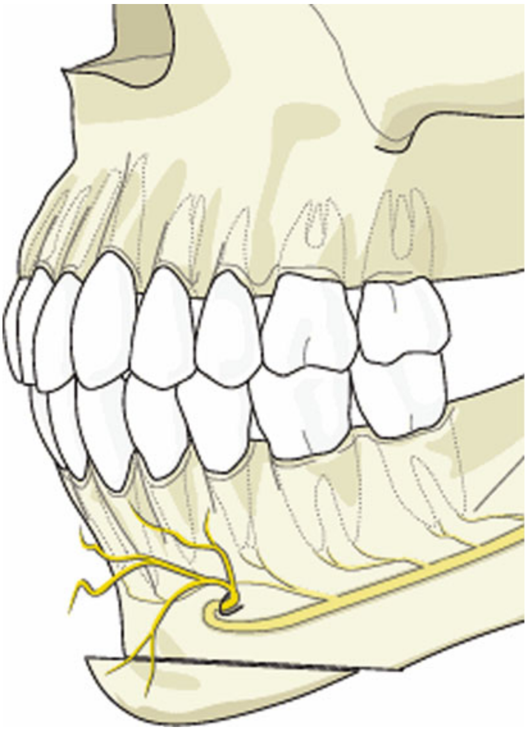

Fig. 8.3 Genioplasty procedure of the anterior mandible places the IAN and mental nerve terminal branches at risk for injury

a sharp probe only. Patients who did not respond to such a stimulus were considered to have an NSD. The more sophisticated the evaluation methods used, the more NSD could be detected. This author compared subjective evaluation and objective assessment of neurosensory function in patients who, after SSRO, had a self-reported NSD of varying degrees [23]. The examination modalities used included the visual analogue scale (VAS), light touch perception, and perception thresholds of warm and cold temperatures. The results indicated that there was a relatively good positive correlation between subjective evaluation and objective assessment of the sensitivity of the lower lip and chin after SSRO of the mandible. In another paper in the same thesis this author reported on IAN function after mandibular osteotomies [21]. For SSRO the data was based upon 548 operated sides with a minimum follow-up time of 2 years. The neurosensory function was evaluated on a 5° scale, where 5, fully normal sensitivity; 4, almost normal sensation; 3, reduced sensation; 2, almost numb; and 1, numb. The distribution was the following: score 5, 61 %; score 4, 22 %; score 3, 14 %; score 2, 2 %; and score 1, 1 %. Interestingly, the two worst scores (scores 1 and 2), representing about 3 % of the operated sides, corresponded well with the previously mentioned reports, where NSD was considered present if the patient did not respond to sharp probing. With the low numbers in the two worst groups, these were added into group 3. Then, the figures indicated that of the operated sides 60 % had fully normal sensitivity of the lower lip and chin, 20 % had a very slightly reduced sensitivity, and 20 % had a reduced sensitivity. The difference between groups 2 and 3 was that in group 2, with a very slight neurosensory disturbance, the abnormal sensation was barely perceptible, while in group 3, the patients were subjectively aware of their NSD. The distribution of "60-20-20" fell very much in the middle of the previously mentioned list of reports and has been supported in later studies with a similar methodological approach.

What, then, is the cause of NSD after SSRO? As mentioned above, the SSRO procedure osteotomizes the mandible along a substantial part of the body, angle, and ramus regions. Therefore, it is generally thought that NSD follows direct trauma to the IAN during the actual osteotomy procedure. This author studied how NSD after SSRO correlated with intraoperative nerve encounter and other variables in 496 operations [22]. From the information contained in the surgical operative reports about nerve encounter during the splits, the nerve was described as one of the following: not exposed at all, visible in the medial fragment, free in between the fragments, dissected from the lateral fragment/superficial damage to the nerve, deep damage into the nerve trunk, and nerve transection. Other study variables included patient age, degree of mandibular movement, type of osteosynthesis used, and surgeon skill/experience. Patient age had a significant influence on the recovery of neurosensory function. The mean age of the patients in the study was 26 years, the median age was 22, and the 25 and 75 percentiles were 18 and 33 years, respectively. Both when the

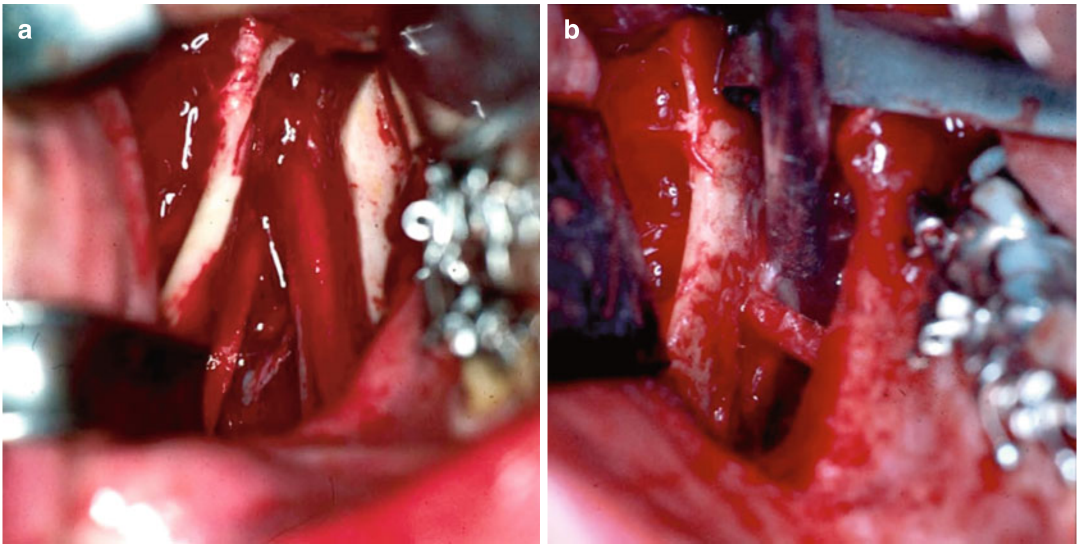

Fig. 8.4 (**a**) IAN is visualized between the proximal and distal segments during an SSRO procedure. (**b**) The IAN is entrapped in the proximal segment; this is associated with a higher incidence of NSD following SSRO surgery

patient series was divided at the median and when the youngest and oldest quartiles were compared with the mid-half, there were significant differences in sensitivity scores. The largest differences were found between the youngest and oldest quartiles. The severity of the neurosensory disturbances was also increased with age.

Intraoperative nerve encounter, however, correlated with NSD to a much lesser degree than expected. While there were more NSD and more severe NSD among the sides where the nerve had been manipulated more extensively in the split, there were also many of those who demonstrated very good neurosensory function. Those sides where the nerves were embedded in the distal fragments did better than those with nerves embedded in the proximal segments (Fig. 8.4), but even among them, there were those with more or less severe NSD. All in all, the nerve encounter as such did not seem to be the only factor involved in the occurrence of NSD. It was suggested that the soft tissue dissection on the medial aspect of the ramus partly may compress the nerve over the lingula and under the dissecting instrument, and partly stretch the nerve between the two (Fig. 8.5). Lingual nerve injury is much less common than inferior alveolar nerve injury, but it may occur possibly from nerve manipulation on the medial ramus or from screw overpenetration during fixation of the proximal and distal fragments [19, 25].

Both compression and stretching of a nerve may seriously harm the nerve function. Interestingly, when the results of surgeons in training were compared with those of the consultant or attending surgeon, there was a significant difference in favor of the experienced surgeon. Realizing the relative difficulty with the soft tissue dissection, it might not come as a major surprise that the inexperienced surgeon might spend a longer amount of time there, and may run a larger risk of causing nerve compression and stretching during the dissection, and during the time it takes to perform the horizontal cut. Several attempts have been made to observe such dissection trauma, for example, by means of trigeminal somatosensory-evoked potentials (TSEP). With this neurophysiological testing modality, the nerve impulses along a nerve can be observed both during the dissection phase and under resting conditions. By monitoring TSEP [8], support for the idea that the soft tissue dissection on the medial aspect of the mandibular ramus might significantly compress the nerve was obtained. It was stated, however, that TSEP in the surgical setting could be obtained "only with some difficulty."

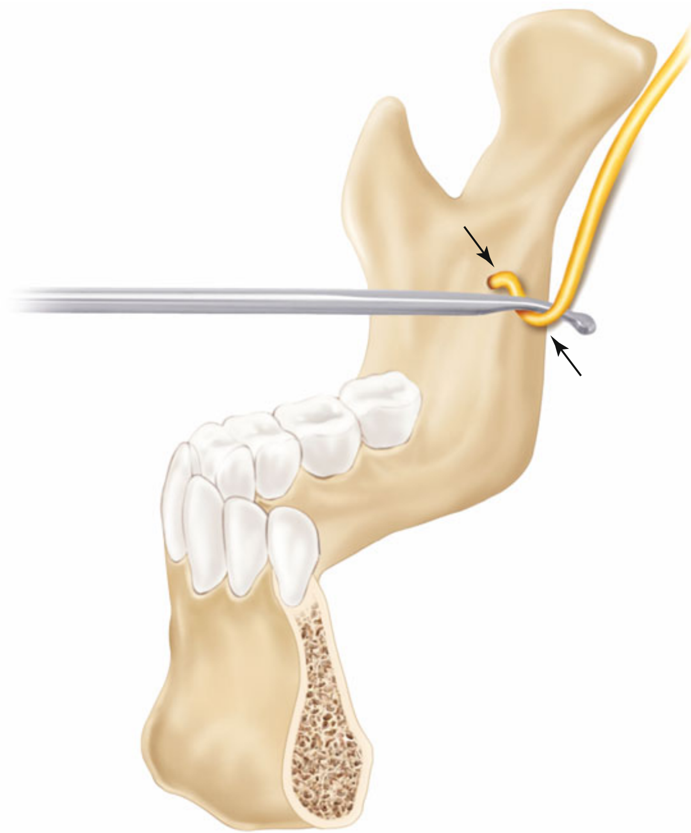

Fig. 8.5 Medial retraction during SSRO may cause IAN compression and contribute to postoperative NSD

Neither the type of osteosynthesis applied nor the direction or degree of mandibular movement played a significant role in the occurrence of postoperative NSD. When bicortical screws are used for the stabilization of SSRO fragments, care should be taken, of course, to avoid the course of the nerve trunk. Also, one should avoid using a lag screw technique, since this technique compresses the fragments toward each other, and there is a risk of nerve trunk compression. Also, there seems to be no difference in postoperative neurosensory function if the bone fragments after SSRO have been stabilized with metal or with biodegradable osteosynthesis [24].

The impact of age has been widely discussed in the literature. Not only the frequency but also the impact of NSD seems to be higher in advanced ages. The better outcome in the younger individuals may depend upon two factors. Partly, the young patient may possess a better capacity of nerve regeneration as such, and partly, the adaptation to a NSD may be easier in a young than in an elderly patient. Recently Baas et al. [4] demonstrated an age-related increase in NSD after sagittal split of the mandible. In the same paper they also found that there was no significant difference in neurosensory function after mandibular advancement done by sagittal split osteotomy or by distraction osteogenesis of the mandible. In another study of subjective paresthesia following 68 SSRO procedures [12], 62 % of patients had NSD at 2 months, 38 % NSD at 6 months, 32 % NSD at 18 months, and 24 % subjective paresthesia at 30 months. The most important factors included age >30, method of fixation (lag screw worse than mini-plate worse than wire fixation), and perioperative position of the IAN

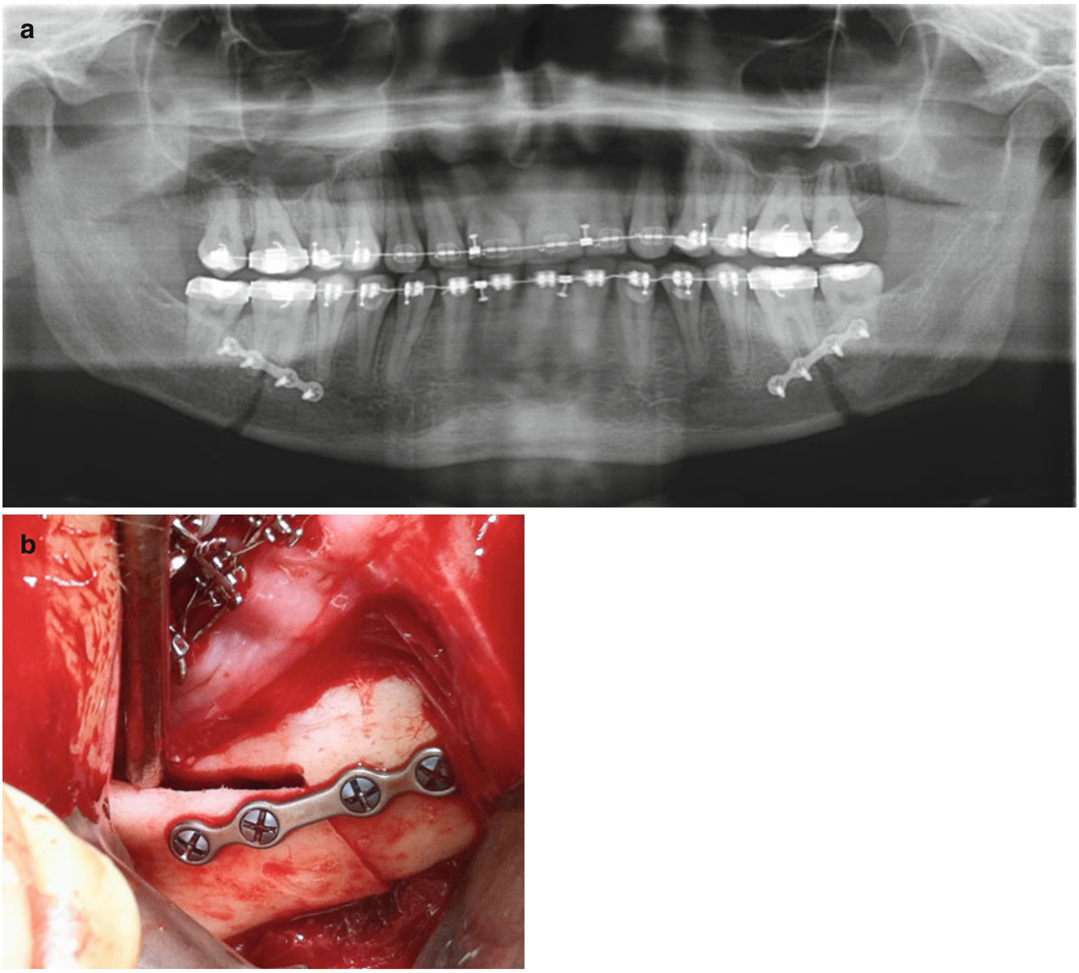

Fig. 8.6 (**a**) Panoramic radiograph demonstrating monocortical plate and screw fixation following SSRO surgery. (**b**) Intraoperative view of monocortical plate and screw fixation of an SSRO procedure. This technique helps to prevent unnecessary compression of the IAN between the bony segments (Courtesy of Michael Miloro)

(worse if located in the proximal segment than the distal segment). In general the monocortical mini-plate permits passive contact of the proximal and distal segments without compression on the IAN (Fig. 8.6).

There are several other risk factors for IAN injury during SSRO surgery including the use of thin chisels that may cause iatrogenic injury. In addition, female gender may play a role in NSD since it has been shown that females recover slower and less fully than males following nerve injuries. The presence of third molars and concomitant removal during SSRO may increase the incidence of NSD since there may be additional nerve contact or manipulation during the odontectomy procedure. The occurrence in advertent osteotomies, or bad splits, also increases the risk of IAN NSD. Finally, it has been shown that in class II retrognathic patients, the inferior alveolar canal may be closer to the buccal cortex and therefore at higher risk of injury during an SSRO procedure [6]. In addition, with severe mandibular deformities such as hemifacial microsomia or Treacher Collins syndrome cases, the position of the inferior alveolar canal may be extremely variable.

While the use of corticosteroids perioperatively has been shown to decrease edema as well as perineurial edema, studies have shown [2] that the difference is not statistically significant. In this questionnaire study of 43 patients more than 1 year after SSRO, 11.6 % reported long-term subjective NSD. Most of the patients reporting NSD were woman over 40 years of age at the time of SSRO. While only 15 % of patients who received perioperative steroids reported NSD and 30 % of patients without steroids reported NSD, the results were not statistically significant.

8.2.2 Vertical Ramus Osteotomy (VRO) and Genioplasty

Vertical ramus osteotomy (VRO) and genioplasty procedures are associated with less postoperative NSD than SSRO. Again, there are variations in the incidence reported, and those may depend upon how the NSD has been evaluated. An incidence below 10 % for VRO and genioplasty seems realistic [7, 20, 21]. The lower risk of NSD after VRO compared with SSRO is a reason why VRO is still used in some centers, despite the morbidity of intermaxillary fixation that follows the procedure. Many centers have abandoned VRO because of the possible threat to the airway in an edematous postoperative patient with IMF. Another limitation is that the VRO can be used only for mandibular setback movements.

Hand surgeons use a definition called double-crush injury, which relates to a situation when one nerve has crush damages at two distinct sites. Such a situation may occur in orthognathic surgery, too, if a ramus osteotomy is combined with a genioplasty. In this authors research [20, 21], there was a tendency toward a higher incidence and increased severity of the NSD when genioplasty was added to both VRO and SSRO. Those tendencies were not, however, statistically significant, but were supported by others [15] who reported more NSD after SSRO combined with genioplasty than after SSRO alone. In one study (Lindqvist and Obeid 1996) the incidence of NSD with genioplasty alone was 10 %, and it was 28.5 % in cases of genioplasty combined with SSRO surgery [9].

8.3 Maxillary Osteotomies

While disturbances in the IAN after mandibular osteotomies have been documented in numerous publications, the maxillary nerve has not attracted the same attention in the literature. A one-piece Lefort I osteotomy (LFO) can be carried out in a relatively safe distance from the infraorbital nerve (ION). Still, if one does not pay attention, the retracting instruments may create a substantial compression of the ION where it exits the bone through the infraorbital foramen. Also, the mucosa in the upper vestibule is incised and the nerves to the marginal gingiva will usually be transected. In addition, plate and screw fixation may also compromise the ION due to proximity in placement. Even so it seems to be a general assumption that LFO is not followed by sensory impairment of a degree that requires the same words of warning that surgeons claim for mandibular osteotomies. Such an assumption, however, is not correct.

Thus, in one study [14] 59 patients who were 1 year after LFO were studied, and it was found that somatosensory function in the distribution area of ION was incomplete compared with the preoperative condition. Another study [11] made 2- and 8-year follow-up examinations with both objective measurements and self-reported sensitivity evaluations. They reported changes in somatosensory function in 17–43 % of their patients, depending upon type of assessment. Another study [17] observed that 1 month after LFO, 81 % of patients demonstrated hypoesthesia in the distribution area of the ION and that 1 year after surgery, only 6 % of the patients had persistent hypoesthesia. Other investigators [16] found that somatosensory function in the skin innervated by ION was normalized 6 months after LFO, while the recovery of sensory function in the palate was incomplete. Similar findings were reported by others [3].

Recently, a study [18] investigated ION function after LFO in a prospective and more standardized fashion. The patients reported an array of sensory disturbances both in the skin and in their intraoral soft tissues. There were tooth sensitivity disturbances that obscured the patient's impression of occlusal conditions. Apart from hyposensations, there were also hyper-sensations reported. In summary, these findings demonstrated subjective changes in somatosensory function of the ION in 7–60 % of the patients, depending upon the site of measurement, 1 year after LFO. Still, they noted that 100 % of their patients were satisfied with the outcome of their surgical procedures and would elect to undergo surgery again.

These observations probably reflect the previously mentioned assumption that the somatosensory disturbances of the ION after LFO are of such a low magnitude causing little subjective complaints that they are of a more academic than clinical interest. Still, however, they should not be ignored, and patients should be properly informed prior to surgery.

8.4 Allodynia

It sometimes occurs that a traumatized sensory nerve produces pain as a response to a stimulus that normally should not result in pain (e.g., light touch). This condition is called allodynia, and it can also occur in a sensory nerve with hypofunction. Thus, a patient can have an increased threshold for light touch and at the same time react with intense pain upon a stimulus that should be experienced as light touch. This is probably the worst somatosensory dysfunction of all that can follow orthognathic surgery. A bilateral loss of light touch sensitivity of the lower lip and chin with addition of intense pain upon touch is a condition that will require a great deal of tender care from the surgeon, preferably with the aid of a neurologist for pharmacologic management.

8.5 Preoperative Considerations

How should we best prepare our patients for the possibility of an NSD after SSRO? Pragmatically, it is fair to say that every patient (100 %) will have some degree of NSD directly after surgery. In the majority of patients, the sensitivity of the lower lip and chin will improve over the first several weeks following surgery, and the majority will return to a normal, or almost normal, sensitivity.

If the patient asks about a more precise prediction, it becomes more difficult to determine such a percentage of NSD based upon a wide variation in the literature. We can accept the figures of 60-20-20, representing the percentages for fully normal sensation, almost normal sensation, and reduced sensation of the lower lip and chin per the operated side after SSRO. Then we can proceed in two different manners to describe what may result in the long term.

On the one hand we could consider NSD as a clinical condition and suggest that those with almost normal sensitivity are so close to normal that they do not have significant symptoms and therefore may be included in the normal sensitivity group. In this case, the risk of permanent NSD is 20 % per operated side, or actually slightly below 20 %, since the groups were equilibrated as described above. Then, we can inform patients in this fashion based upon solid statistical evidence.

On the other hand, we could be more academic about this matter and use the statistics to describe the complete risk of obtaining some, even the slightest, type of NSD on either, or both sides, of the lower lip and chin. If we maintain the 60-20-20 rule, the percentage for almost normal and reduced sensitivity will be 40 %. The formula for any type of NSD on either or both sides of the lower lip and chin then will be calculated as follows: $(0.4+0.4) - 0.4 \times 0.4 = 0.8 - 0.16 = 64$ % chance of NSD following SSRO.

Thus, depending upon how we present the same material to patients, we can do it with widely varying presumptions, while remaining more or less truthful about the percentages. With increasing age and experience, this author has found it increasingly valuable to be very frank about the risk of obtaining permanent NSD after orthognathic surgery. In general, the more time that passes after the SSRO procedure, the less the significance of the NSD to the patient.

8.6 New Research on Orthognathic Nerve Injuries

When molecular biology started to find keys to a lot of growth factors that are steering and modulating tissue formation and healing, great hopes grew that one day nerve growth factors and similar substances might be used to improve recovery of function after injuries to both sensory nerves and motor nerves, whether the injury being caused by trauma or by elective surgery. So far, however, these substances have not been introduced in everyday surgical activities.

Advances in diagnostic tools have made it easier to observe complicating inferior alveolar nerve anatomy and position, by which some traumatic nerve interferences during SSRO can be avoided [1].

Also, the mere understanding of a possible dissection trauma, where a procedure performed to protect, in fact may harm the nerve, has helped to shorten that particular process in order to reduce the impact on the nerve in SSRO.

Recent studies also have brought our attention to aspects previously hardly considered. Thus, a paper by Doucet et al. [5] indicated that if impacted third molars were removed during SSRO, rather than before, the incidence of NSD was reduced.

Even though these new research findings seem to reduce NSD after SSRO, they do not eliminate NSD. Orthognathic surgery will for a long future to come continue to produce NSDs of various degrees and severity.

Another study [10] used low-level laser (LLL) treatment perioperatively for six patients undergoing SSRO surgery. The IAN was treated at the mandibular foramen, mental foramen, and lower lip and chin region using a gallium-aluminum-arsenide (Ga-Al-Ar) laser at 820 nm. It was found that brushstroke directional discrimination was normal at 14 days and two-point discrimination thresholds were normal by 8 weeks in all patients. There were few abnormalities in thermal discrimination and pinprick nociception, but in those that did occur, they tended to last longer (>2 months). Using a VAS scale, patients reported a 50 % deficit at 2 days and only 15 % at 8 weeks. This LLL treatment shows promise in management of difficult and long-lasting nerve injuries, but may also be used, as in this study, preemptively in order to prepare the IAN for the expected surgical insult and expected paresthesia to decrease the incidence of long-term NSD.

8.7 Recommendations

In order to attempt to avoid IAN injury during SSRO surgery, there are several considerations that can be useful. The vertical osteotomy should be made in the first or second molar region to avoid the most lateral position of the IAN in the third molar region. Also, the depth of the osteotomy should be limited to 2–3 mm in the first molar region to avoid the IAN. The horizontal osteotomy should be made at a reasonable distance above the mandibular foramen on the medial aspect of the ramus to avoid the IAN as it enters the mandible. Care should be taken to avoid significant compression of the IAN during medial retraction for the horizontal osteotomy. The use of thin sharp chisels should be avoided in favor of larger chisels to initiate the osteotomy only and then the use of a spreading instrument (e.g., Smith spreader) to complete the SSRO.

The management of IAN injuries is similar to the management of IAN injuries due to other causes. Intraoperative transection of the IAN may necessitate a corticotomy to the mental foramen in order to mobilize the nerve enough for primary neurorrhaphy (Fig. 8.7). As mentioned, persistent decreased sensation is usually well tolerated and no specific treatment is recommended. The decision to explore the IAN surgically must be weighed against the risks of additional nerve injury from the surgical exposure (or malocclusion if the approach is an SSRO approach). If allodynia or dysesthesia is the predominate symptom, then consultation with a neurologist is indicated for pharmacologic management. Again, younger patients are typically better able to tolerate nerve injuries than older patients, and, in the majority of cases, no specific treatment is recommended.

8.8 Summary

From what has been described in this chapter, it is clear that it would be of great academic value if the maxillofacial surgery community in cooperation with neurology counterparts could agree

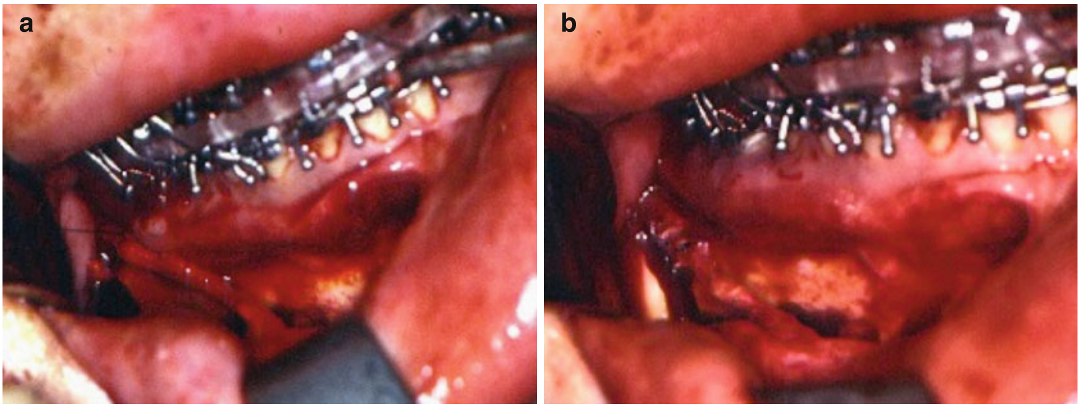

Fig. 8.7 (**a**) Intraoperative view of right IAN transection during SSRO mandibular advancement. Note epineurial suture placed through proximal and distal nerve stump. (**b**) Decortication of the lateral mandible to the mental foramen in order to mobilize the IAN for direct repair using epineurial sutures (Courtesy of Michael Miloro)

upon a universal method to measure and evaluate somatosensory function, although from a clinical point of view it is the patient's subjective perception of sensation that is most important and should guide treatment recommendations. There are patients who do not care a great deal about NSD even when we measure severe sensitivity loss objectively and others in whom we can hardly detect a sensory loss objectively, but for whom the subjective experience can be very disturbing. Here, as in many other areas of maxillofacial surgery, preoperative information, preoperative evaluation, and patient selection are key factors to what we call treatment success. In general, patients are willing to tolerate mild NSD in order to correct a dentoskeletal discrepancy with improvement in esthetics and function. As mentioned, the younger the patient, the better they will tolerate the NSD and the better the NSD will recover quicker and to a higher level spontaneously than in the older patient. But for all patients, it is helpful to remember that, generally, the significance of the NSD decreases as the time from SSRO increases, indicating that recovery occurs in most patients almost fully, or at least their perception of the NSD improves with time.

We have come a long way from the days when discussions about SSRO did not even include considerations about neurosensory disturbances, but still, we must remember one of the rules of all surgeons is "primum non nocere" (first, do no harm).

References

1. Aizenbud D, Ciceu C, Hazan-Molina H, Abu-El-Naj I (2012) Relationship between inferior alveolar nerve imaging and neurosensory impairment following bilateral sagittal split osteotomy in skeletal class III cases with mandibular prognathism. Int J Oral Maxillofac Surg 41:461–468
2. Al-Bishri A (2004) On neurosensory disturbance after sagittal split osteotomy. J Oral Maxillofac Surg 62:1472–1476
3. Al-Din OF, Coghlan KM, Magennis P (1996) Sensory nerve disturbance following Le Fort I osteotomy. Int J Oral Maxillofac Surg 25:13–19
4. Baas EM, Horsthuis RBG, de Lange J (2012) Subjective alveolar nerve function after bilateral sagittal split osteotomy or distraction osteogenesis of mandible. J Oral Maxillofac Surg 70:910–918
5. Doucet JC, Morrison AD, Davis BR, Gregoire CE, Goodday R, Precious DS (2012) The presence of mandibular third molars during sagittal split osteotomies does not increase the risk of complications. J Oral Maxillofac Surg 70(8):1935–1943
6. Hallikainen H (1992) Cross-sectional tomography in evaluation of patients undergoing sagittal split osteotomy. J Oral Maxillofac Surg 50:1269–1273
7. Hoenig JF (2007) Sliding osteotomy genioplasty for facial aesthetic balance: 10 years of experience. Aesthetic Plast Surg 31:384–391
8. Jones DL, Wolford LM, Hartog JM (1990) Comparisons to assess neurosensory alterations

following orthognathic surgery. Int J Adult Orthodon Orthognath Surg 5:35–42
9. Lindqvist CC, Obeid G (1988) Complications of genioplasty done alone or in combination with sagittal split ramus osteotomy. Oral Surg Oral Med Oral Pathol 66:13–16
10. Miloro M, Repasky M (2000) Low level laser effect on neurosensory recovery following sagittal ramus osteotomy. Oral Surg Oral Med Oral Pathol 89: 12–18
11. Nardi P, Guarducci M, Cervinio M (2002) Orthognathic surgery. Study of nerve injuries. Minerva Stomatol 51:461–471
12. Nesari N (2005) Neurosensory function of the inferior alveolar nerve after bilateral sagittal split osteotomy. Int J Oral Maxillofac Surg 34:495–499
13. Obwegeser H (1964) The indications for surgical correction of mandibular deformity by the sagittal splitting technique. Br J Oral Maxillofac Surg 7:157–171
14. Posnick JC, Al Qattan MM, Pron G (1994) Facial sensitivity in adolescents with and without clefts 1 year after undergoing Le Fort I osteotomy. Plast Reconstr Surg 94:431–435
15. Posnick JC, Al-Qattan MM, Stepner NM (1996) Alteration in facial sensibility in adolescents following sagittal split and chin osteotomies of the mandible. Plast Reconstr Surg 97:920–927
16. Rosenberg A, Sailer HF (1994) A prospective study on changes in the sensitivity of the oral mucosa and the mucosa of the upper lip after Le Fort I osteotomy. J Craniomaxillofac Surg 22:286–293
17. Schultze-Mosgau S, Krems H, Ott R, Neukam FW (2001) A prospective electromyographic and computer-aided thermal sensitivity assessment of nerve lesions after sagittal split osteotomy and Le Fort I osteotomy. J Oral Maxillofac Surg 59:128–138
18. Thygesen TH (2008) Somatosensory function after Le Fort I osteotomy xperimental and clinical studies. Thesis, Faculty of Health Sciences, University of Aarhus, Aarhus
19. Triplett G (1996) Lingual nerve injury due to overpenetration of bicortical screws for sagittal split osteotomy. J Oral Maxillofac Surg 54:1451–1453
20. Westermark A (1999) On inferior alveolar nerve function after sagittal split osteotomy of the mandible. Thesis, Karolinska Institute, Stockholm
21. Westermark A, Bystedt H, von Konow L (1998) Inferior alveolar nerve function after mandibular osteotomies. Br J Oral Maxillofac Surg 36: 425–428
22. Westermark A, Bystedt H, von Konow L (1998) Inferior alveolar nerve function after sagittal split osteotomy of the mandible: correlation with degree of intraoperative nerve encounter and other variables in 496 operations. Br J Oral Maxillofac Surg 36:429–433
23. Westermark A, Englesson L, Bongenhielm U (1999) Neurosensory function after sagittal split osteotomy of the mandible – a comparison between subjective evaluation and objective assessment. Int J Adult Orthodon Orthognath Surg 14:268–275
24. Yoshioka I et al (2012) Comparison of material-related complications after bilateral sagittal split mandibular setback surgery: biodegradable versus titanium miniplates. J Oral Maxillofac Surg 70: 919–924
25. Zuniga J (1990) Lingual nerve injury as a complication of sagittal split osteotomy. J Oral Maxillofac Surg 48:647–648