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Analysis of an in-house technique for temporary mandibulotomy and its impact on postoperative radiotherapy

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Abstract. The purpose of this study was to describe a newly developed procedure for temporary mandibulotomy and subsequent osteosynthesis. Clinical outcomes were evaluated, including complications and the impact on postoperative treatment, particularly postoperative radiotherapy. Twenty-four patients underwent temporary mandibulotomies for the surgical resection of malignancies located in the posterior oral or oropharyngeal region. All were treated with postoperative radiotherapy. An angulated median mandibulotomy was followed by osteosynthesis with three anchor screws directed towards the inferior aspect of the mandible. Anchor screws are modified conventional lag screws that include an additional biconcave washer. This modification prevents the screw heads from cracking into the cancellous bone during tightening, improving their biomechanical qualities considerably. Insertion of screws at any angle to the bony surface therefore becomes possible, which is a precondition for this technique. Minor complications occurred in two patients in the early postoperative period. However, complications causing bony non-union, leading to postponed postoperative radiotherapy were not noted in this cohort.

Key words: temporary mandibulotomy; osteotomy design; anchor screw osteosynthesis; fracture healing; postoperative radiotherapy.

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The temporary mandibulotomy (TM) provides suitable surgical access to malignancies located in the posterior oral and oropharyngeal region and represents a basis for safe resection and reconstruction. As a consequence, TM may provide improved long-term outcomes[1]. Nevertheless, although the procedure has benefits, there is the possibility that complications could delay postoperative treatment, e.g. radiotherapy, thereby reducing its efficacy. Indeed, TM may be accompanied by considerable complication rates[2]. A reliable technique of osteotomy and osteosynthesis that allows primary bone healing and offers the lowest possible risk of complications is a precondition for the efficient timing of postoperative radiotherapy (PORT).

There is some evidence in the literature that a delay in the start or completion of PORT has a considerable negative impact on the outcome[3,4]. PORT should ideally start within 4 weeks after surgery[3,5].

However, as known from the study of mandibular trauma, bone healing takes 6 weeks[6], which means that the last third of the healing period would have to take place during radiotherapy. Different techniques for osteotomy (median[7–10] and paramedian[2,11–15]) with various designs[16,17] and osteosynthesis materials (miniplates[2,13,15,17,18], rigid plates[7,12,19,20], and lag screws[8–10,16,21]) have been reported in the literature.

Based on experience in the treatment of mandibular fractures with anchor screw osteosynthesis, an in-house temporary mandibulotomy technique was developed that combines a median angulated osteotomy and lag screw osteosynthesis with three parallel anchor screws, positioned towards the inferior aspect of the mandible. This is referred to as the standard procedure for temporary mandibulotomy in this article. The procedure allows for safe healing of the osteotomy site, thus avoiding delays in the process of PORT.

Materials and methods

Patients

Between 1999 and 2014, a total of 57 patients underwent the standard temporary mandibulotomy procedure. This study included 24 patients with a diagnosis of squamous cell carcinoma (primary tumours $n = 19$, recurrent tumours $n = 5$) located in the posterior oral cavity or the oropharynx, without traceable invasion of the mandible or its periosteum, for retrospective analysis of the technique. The following inclusion criteria were applied: (1) application of the in-house technique for mandibulotomy, and (2) administration of PORT with the osteotomy site being within the irradiation field.

Patients who had undergone preoperative radiotherapy were excluded from the analysis. Detailed data on the characteristics of the study patients are listed in Table 1. Patients were followed up clinically and radiologically for at least 1 year after surgery, in the context of standardized care.

Data analysis

Data collected from patient records for the retrospective analysis of the technique included surgical parameters, parameters of PORT, and the occurrence of treatment-related complications, immediately after surgery or during clinical follow-up. Surgical parameters included use of the lip-splitting technique, additional partial mandibulectomy (alveolar rim resection) – if necessary, state of the dentition, and possible application of titanium dental ring splints during surgery. Parameters of PORT included the timing of PORT in relation to surgery, duration of application, and overall treatment time. Moreover, the overall median irradiation dose at the cancer site, the median dose at the osteotomy site, and the modality of PORT were also evaluated. Possible treatment-related complications included impaired wound healing, bony non-union, exposure of osteosynthesis material, osteoradionecrosis in the irradiation field, osteoradionecrosis at the mandibulotomy site, lesions of the mental nerve, loss of teeth, and lesions of the tooth roots.

Surgical technique

After straight or curved lip-splitting, the bony surface of the chin area was exposed. The median osteotomy line, angulated at around 45°, was traced with a thin cutting bur (rose head bur, 1.4 mm). The inferior branch of the angle was orientated towards the side of the tumourous lesion to shorten the access route and to improve the view of the surgical field. Prior to performing the osteotomy, three anchor screws were inserted. They were positioned near vertical to the inferior arm of the angulated osteotomy line towards the inferior aspect of the mandible, allowing visual control of the bicortical anchorage. Anchor screws are modified lag screws (Fig. 1); an additional biconcave washer improves their biomechanical qualities (Fig. 1C) by preventing the screw head from cracking into cancellous bone or causing burst fractures of thin cortical layers during tightening (Fig. 1A, B). For anchor screw fixation, the gliding hole was prepared with a 2.0-mm drill as far as the level of the estimated osteotomy line. Supported by a drill guide, the traction hole was cut with a 1.5-mm drill, penetrating the opposite cortical layer. The reciprocal countersink for the biconcave washer was subsequently cut with a countersink drill (Fig. 2). Measurement with a depth gauge was used to determine the screw length before tapping of the traction hole. The screws were inserted one by one (Fig. 3).

After removal of the osteosynthesis materials, the TM was performed using an oscillating saw with an ultrathin saw blade (0.35 mm). In some cases, the osteotomy in the region of the alveolar process, between the roots of the inferior incisors, was completed with an osteotome. This can create additional tines, which can improve the friction in the osteotomy line. After tumour resection, the mandibular fragments were re-approximated and fixed with the screws prepared in advance (Fig. 4). In cases with appropriate dentition (at least tooth 33 up to tooth 43), a titanium dental ring splint was applied. In all cases, a strict regime was followed for the prophylactic preoperative removal of teeth likely to create problems during PORT.

Table 1. Epidemiological data for the patients included in the retrospective analysis.

Number of patients	24
Sex	4 female, 20 male
Age (years), median (range)	61.7 (47.5–77.5)
Histopathology, SCC	24 (100%)
Primary disease	19 (79.2%)
Recurrent disease	5 (20.8%)
Cancer sites	
Oral cavity	10 (41.7%)
Oropharynx	10 (41.7%)
Oral cavity + oropharynx	4 (16.6%)
Tumour stage	
pT2	7 (29.2%)
pT3	11 (45.8%)
pT4	6 (25.0%)
Duration of clinical follow-up (months), median (range)	41 (12–105)

SCC, squamous cell carcinoma.

Results

Surgical parameters

Surgical procedures were performed by four different surgeons. Either straight lip-splitting was performed ($n = 15$) or curved incisions were used ($n = 9$), according to surgeon preference. Tumour resection was combined with partial mandibular (alveolar rim) resection in four cases in order to provide safe margins. A titanium dental ring splint was attached in patients with full dentition at the mandibulotomy site ($n = 10$).

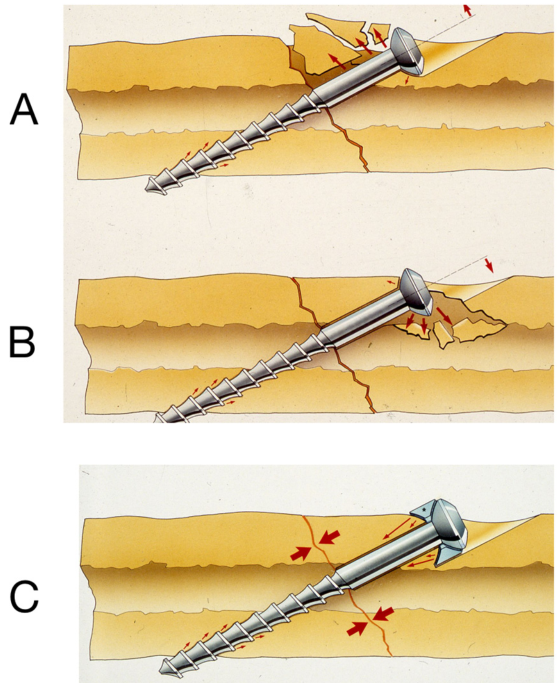

Fig. 1. Illustration of conventional lag screws (A, B) and an anchor screw (C). Potential traumas to the bone during tightening of conventional lag screws are shown: (A) burst fractures of the thin cortical layers caused by wedge action of the screw head, and (B) penetration of the screw head into cancellous bone. An anchor screw (C) includes a biconcave washer (*), which prevents the adverse biomechanical effects of a conventional lag screw.

PORT parameters

For the whole sample, the median interval between surgery and PORT was 36.6 days (range 25.0–53.0 days). The median duration of PORT was 49 days (range 30.0–72.0 days). The resulting median overall treatment time was 84.9 days (range 59.0–111.0 days). The median overall irradiation dose at the cancer site for all patients ($n = 24$) was 58.8 Gy (range 42.5–71.4 Gy).

Details of the irradiation dose at the mandibulotomy site were available for 19 patients; five patients received PORT at institutions elsewhere. Three of the 19 patients with available irradiation reports received three-dimensional conformal radiotherapy with photons and electrons as shrinking fields or conformal arc therapy, with a median dose of 54.0 Gy (range 48.0–66.0 Gy). Twelve patients underwent the laterally opposed shrinking field technique with photons and electrons, with a median dose of 58.0 Gy (range 30.0–71.4 Gy). Four patients had intensity modulated radiotherapy with the step and shoot technique, with a median dose of 57.0 Gy (range 48–65 Gy). The median dose at the osteotomy site for all 19 patients receiving PORT at the study institution was 55.9 Gy (range 30.0–71.4 Gy).

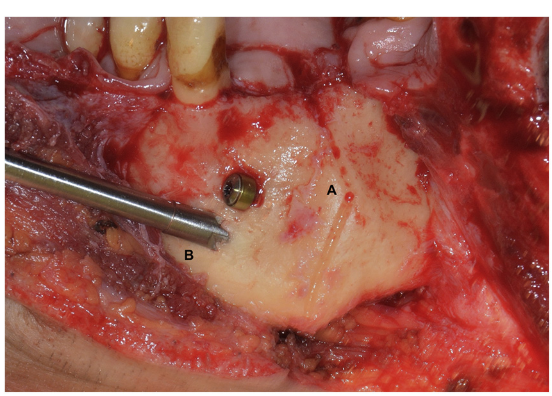

Fig. 2. Preparation of anchor screw osteosynthesis in the procedure described: after tracing the angulated osteotomy line (A) and drilling the gliding and traction hole, the countersink for the second screw is prepared with a countersink drill (B).

Treatment-related complications

During clinical follow-up, complications with minor disturbances in wound healing were observed at two sites (8.3%) in the early postoperative period. One patient showed wound dehiscence without exposure of the screw heads and the other patient had an intraoral fistula. These sites healed uneventfully with the use of local therapy and there was no delay in the course of PORT in either case. No cases of bony non-union were noted. Exposure of the osteosynthesis material was not noted in any of the cases either. One patient who had received PORT with the laterally opposed shrinking field technique with photons and electrons, developed osteoradionecrosis at the lateral aspect of the mandible, which had been within the irradiation field. However, there was no impairment of the mandibulotomy site in this patient. There was no case of osteoradionecrosis or osteomyelitis at the mandibulotomy site, nor was there any case of malunion, malocclusion, or lesions of the mental nerve or tooth roots. No loosening or loss of teeth as a consequence of the surgical procedure was seen during the observation period. An overview of all of these parameters is given in Table 2.

Discussion

Reports on various techniques for TM have been published. Alternative techniques, such as the mandibular genial osteotomy[22] and the mandible-preserving pull-through technique[23], as well as procedures without lip splitting[11], do not provide comparable access to the regions of interest. Devine et al.[24] found no difference in the functional outcome between the lip-split mandibulotomy and pull-through techniques.

Vertical or modified vertical lip-splitting[2,9], semicircular techniques[7], and non-lip-splitting TM techniques[11] have been described. With non-lip-splitting techniques, a reduction of the benefits of TM in terms of overview of the surgical field and safety of resection would be expected.

Some authors have advocated the median osteotomy for various reasons[7–10], while others have proposed paramedian techniques[2,11–15,25]. The main arguments include avoidance of detachment of the

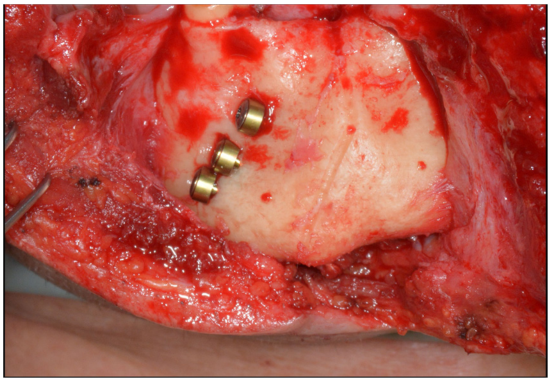

Fig. 3. Completed anchor screw osteosynthesis, prior to mandibulotomy.

Fig. 4. Postoperative panoramic X-ray after temporary mandibulotomy with three anchor screws directed towards the inferior border of the mandible.

muscles[2,10,14,15,18,19], load of the osteotomy area with irradiation[2,7,9,10,12,13,25], effects on the blood supply to the mandible[2,7,10,14], prevention of tooth extraction[13,14,19,25], and loss of teeth due to lesions of the tooth roots[12,19].

Straight osteotomies have been suggested, as they are easy to perform[7–10]. However, various specifically angulated osteotomies[2,11–13,15,17] and osteotomies with uncommon designs[16] have also been proposed, as they improve buttressing of the mandibular fragments and might facilitate osteosynthesis.

The standard procedure with angulated median mandibulotomy used at the study institution combines the advantages of midline and paramidline techniques, avoids potential detachment of the muscles of the floor of the mouth, i.e. the genioglossus, geniohyoid, and digastric muscles, and preserves the tooth roots and the mental nerve. The preservation of muscular function is important for postoperative swallowing abilities and is therefore a major issue for quality of life[26].

There is controversy in the literature regarding the techniques for osteosynthesis as well. Osteosynthesis may either be prepared before the mandibulotomy[7,8,10,12,13,15] or carried out after tumour resection[2,16,25]. A considerable loss of precision with osteosynthesis performed after tumour resection would be expected.

The material used for osteosynthesis has varied considerably among different reports. Miniplates have been used in varying numbers, lengths, and positions, in combination with varying numbers and types of screws[2,11,13,15,17,18,25]. Usually two miniplates are inserted on the outer face of the mandible; however some authors have used only one miniplate, while others have fixed a second miniplate

Table 2. Parameters analyzed for the evaluation of the in-house technique. Detailed information on postoperative radiotherapy parameters was available for 19 patients only.

Surgical parameters (Available for $n = 24$ patients)		PORT parameters (Available for $n = 24$ patients)		Treatment-related complications (Available for $n = 24$ patients)	
Surgeons (*n*)	4	Time interval from surgery to PORT in days, median (range)	36.6 (25.0–53.0)	Impaired wound healing (*n*)	2
Straight lip splitting (*n*)	15	Duration of PORT in days, median (range)	49.0 (30.0–72.0)	Bony non-union (*n*)	0
Curved incision (*n*)	9	Overall treatment time in days, median (range)	84.9 (59.0–111.0)	Exposure of osteosynthesis material (*n*)	0
Partial mandibular resection (*n*)	4			Osteoradionecrosis in irradiation field (*n*)	1
Complete dentition	10	PORT parameters (Available for $n = 19$ patients)		Osteoradionecrosis at mandibulotomy site (*n*)	0
Incomplete dentition	14	PORT Parameters (Available for $n = 24$ patients)	58.8 (42.5–71.4)	Malunion or malocclusion (*n*)	0
Titanium dental ring splint used (*n*)	10	Irradiation dose at mandibulotomy site per patient in Gray, median (range)	55.9 (30.0–71.4)	Lesion of mental nerve (*n*)	0
		Three-dimensional conformal PORT (*n*)	3	Lesion of tooth root (*n*)	0
		Laterally opposed shrinking field PORT (*n*)	12	Loss of teeth (*n*)	0
		Intensity modulated PORT (*n*)	4		

PORT, postoperative radiotherapy.

on the undersurface of the body of the mandible[11,13,15] or have used miniplates with monocortical screws[8,13,17]. There might be a higher risk of instability with monocortical screws or single miniplates. In order to provide greater stability, several authors have recommended rigid plates[7,12,19,20]. However, the bulkiness of rigid plates may lead to problems with soft tissue coverage, especially in patients requiring postoperative radiation[12,19]. Moreover, there is the potential for malunion, resulting in malocclusion, as well as for lesions of the mental nerve or the tooth roots with the use of large plates[12].

Lag screws facilitate compression osteosynthesis[16], reducing the amount of material used[9], as well as the potential danger of extrusion[10]. Compression osteosynthesis allows for primary bone healing without callus formation[8,16] and requires only minimal stripping of periosteum[10]. Danan et al.[21] compared plate and lag screw osteosynthesis and found a considerably higher bony union rate for lag screw osteosynthesis. Serletti et al.[9] applied two conventional lag screws parallel to the occlusal plane after straight midline osteotomy. They reported the need for hardware removal in 26% of the cases due to loosening of the screws.

The screw heads of conventional lag screws may penetrate into the cancellous bone or create burst fractures of the thin cortical layers. This phenomenon is caused by wedge action during tightening of the screws. The potential for harm is even greater when the lag screws are inserted at an oblique angle relative to the bony surface[9,16,27]. These effects are well known from experience with conventional lag screws in the treatment of mandible fractures[27]. The biconcave washer of the anchor screws diminishes this potential risk associated with conventional lag screws[28] and therefore improves the lag principle. There are two reports in which the authors used two anchor screws parallel to the occlusal plane for fixation after straight median osteotomy[8,10]. Both reported moderate complication rates and a low percentage of non-union after radiotherapy, which had been applied in only 61% and 75% of their cases, respectively. The application of anchor screws parallel to the occlusal plane is tricky in terms of predictability of placement. Deviations from the intended orientation may reduce biomechanical performance of the osteosynthesis and cause problems with tooth roots or even the mental nerve. Furthermore, the space provided by this technique will allow the placement of no more than two screws.

The standard procedure used in this study facilitates the handy application of three oblique screws, as well as safe and easy visual navigation towards the target area at the inferior aspect of the mandible. Anchorage of screws in a central position in the mandibular bone represents a precondition for reliable three-dimensional resistance against tensile and torsional forces. As a result, the additional application of tension band devices, as frequently used in miniplate osteosynthesis, was not necessary in the study patients. However, titanium dental ring splints were applied at teeth-bearing mandibulotomy sites to prevent loosening or loss of the median incisors (teeth 31 and 41) close to the osteotomy line. During surgery, these can be applied by bending, etching, and bonding technique within a few minutes. No loosening or loss of median incisors was observed during follow-up.

Complication rates in the literature vary between 0% and 47%, although the descriptions and classifications of complications vary considerably[7,25]. Bony non-union rates of between 0%[7,10,13,15] and 10.4%[20] have been reported. In some reports high infection rates have contrasted with low non-union rates[13,15,18].

The use of an additional partial mandibulectomy has been defined as an exclusion criterion in some studies, due to the potentially higher risk of major complications[2,18,29]. Other authors have not experienced any such problems using this procedure[8,10]. The four patients in the present study who underwent an additional partial mandibulectomy did not show any complications.

The percentage of patients receiving postoperative radiotherapy varies from 47% to 100% in the literature[8,20]. There is very little information on the timing of PORT. Irradiation has been started 4–6 weeks[25] or $\geq$8 weeks[18] after surgery. Shinghal et al.[19] reported a median interval from surgery to PORT of 68 days. In the present study cohort, radiotherapy was started a median of 36.6 days after surgery.

There is disagreement in the literature regarding the possible effects of radiotherapy on mandibulotomy sites[7,18]. Several authors have reported no potential impact on mandibulotomy sites after radiotherapy[13,15,20]. In some reports, no predictors of mandibulotomy-related complications could be identified at all[2,15,20]. Donneys et al.[6] showed a significantly decreased number of osteocytes and a decreased capacity to produce new osteoid in radiated mandibular fractures compared to non-radiated fractures in an animal experiment.

In the present study, the median irradiation dose at the osteotomy site of 55.9 Gy is slightly higher than that reported by Shinghal et al.[19]. They described a mean dose of 53.37 Gy for the median mandibulotomy site and a mean dose of 53.44 Gy for the paramedian site. This difference may be explained by the high percentage of patients in the present sample who were treated with the laterally opposed shrinking field technique.

To date there are no data in the literature on delays in the course of PORT as a consequence of complications after TM. Three critical time-related parameters will have an impact on the outcome of radiotherapy in terms of loco-regional control and survival rates: the interval between surgery and PORT[3–5], the duration of PORT4, and the overall treatment time[30]. Delays in initiating PORT[3,5,30] or in the course of PORT are thought to have a major negative effect on loco-regional control and the survival rates of patients with fast growing tumours in particular. An interruption in the course of irradiation of 1 week was found to be associated with an absolute reduction in loco-regional control rate of 10–12%[4]. Similarly, a prolongation of overall treatment time of 10 days was associated with a 10–20% decrease in 5-year recurrence-free survival[30]. Relevant data in the literature give a clear indication for the correlation between timing of radiotherapy and its efficacy[3].

There remains room for improvement in the management of the timing of PORT at the study institution (median 36.6 days between surgery and the start of radiotherapy, median duration of PORT of 49 days, and median overall treatment time of 84.9 days); however, potential delays in the context of PORT could be avoided by a reduction of mandibulotomy-related complications through use of the standard procedure described.

The study data represent personal experience and lack systematic work-up, e.g. comparison to a matched control group. Moreover, the validity of this study is limited by the common drawbacks of a retrospective design. The development of this in-house technique was based on prior clinical experience with various techniques for osteosynthesis at a tertiary referral hospital. It cannot be concluded from the results that an improvement in outcomes occurred due to the use of this technique. Biomechanical investigations to further explain the promising clinical results obtained with this technique are currently underway.

To conclude, the in-house technique for temporary mandibulotomy described herein appears to allow tumour resection with satisfactory postoperative results and minimal surgery-related complications. Efficient surgery prevents potential delays in postoperative care, possibly leading to improved overall treatment results for patients with malignancies of the oral cavity or the oropharynx.

Funding

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Ethical approval

Ethics exemption was given by the Ethics Committee of the Federal State of Salzburg under number 415-EP/73/607-2015.

Competing interests

None.

Patient consent

Not required. The patient is not identifiable in the two intraoperative photos of a mandibulotomy.

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