

# External pin fixation for stabilization of the mandible—comeback of a method: historical review and first experiences with the ‘mandible external fixator’

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## Abstract

**Background** The market-release of a modified ‘mandible external fixator’ appliance prompted us to reconsider the issues of pin fixation.

**Materials and methods** The first product line of the ‘mandible external fixator set—Phase1’ (Synthes Maxillofacial®, Paoli, USA) contains the three classical basic components: percutaneous pins, clamps, and pre-bent connecting rods. The innovative features are a lightweight titanium construct and the snap-on design of the clamps. The framework is assembled by a single connecting bar (monofixator) in the so-called visor-style technique.

**Indications** The indication was restricted to: (1) pathological fractures, e.g., in infected osteoradionecrosis; (2) resectional defects; and (3) emergency care of mandible fractures in a multi-piece, heavy comminution, or defect pattern.

**Patients** The mandible external fixator was used in a series of ten patients (all male, 39–73 years), for head and neck tumor sequelae in eight cases ( $n=5$ —curatively,  $n=3$ —palliation) and in two polytrauma cases.

**Results** All patients had benefited from the functional restitution of the mandibular continuity avoiding major surgical exposure and additional soft tissue damage. The application using a ‘visor-style technique’ was appropriate for bridging defects or single comminution zones ( $n=9$ ). In the emergency care of a polytraumatized patient with multifragmentation all over the mandible divisions, it did not contribute to an adequate realignment. In curative tumor treatment (patients  $n=5$ ), a conversion either to internal

fixation ( $n=2$ ) or revascularized bone grafting ( $n=3$ ) ensued after prolonged intervals of 40–170 days. Pin track infections or loosening did not occur.

**Conclusion** The hallmark of external pin fixation is its atraumatic soft tissue management. Hence, it offers peculiar options in singular comminution or defect areas associated with bone pathology and/or soft tissue alterations.

**Keywords** External fixator · Mandible · Historical review · Patient series · Visor mode application · Indications for treatment in tumor and trauma

## Introduction

The external splinting of the mandible with pin fixation or with an external fixator appliance, respectively, is nowadays an unusual modality in fracture treatment with an indication confined to a few problematic cases beyond routine.

In the years between 1940 and 1950, external pin fixation was modified for its particular use in mandible fractures and further on was propagated during two time spans (from 1940 to approximately 1975 and from 1985 to approximately 1995). However, with increasing popularity of rigid internal fixation methods in craniofacial trauma and reconstructive surgery, pin fixation began to disappear from the common repertoire and was even attributed to have a touch of anachronism [40].

Accordingly, an external fixator (1988) developed by Spiessl [36] was eliminated from the producer’s portfolio after only a few years “due to lack of indications” [33].

Recently, a new commercial ‘mandible external fixator’ was released (Synthes Maxillofacial®, Paoli PA, USA) with a design and technique based on the previous studies of

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Spiessl. The innovative features are a lightweight titanium construct as a remedy against interferences in modern imaging [computed tomography (CT), nuclear magnetic resonance] as well as convenient technical handling with snap-on clamps to connect the percutaneous pins and the external fixator rods, guaranteeing a stable framework construction.

After a review on the history and development of external fixation osteosynthesis in the mandible, this paper reports on clinical experiences with the initial product line of this new external fixator system and comments on current indications.

### Historical review: annals of the external fixator application in the mandible

The basic idea of percutaneously bone-anchored “external holders” for fracture treatment in extremity areas goes back, among others, to C. Wutzer (1853), J.F. Malgaigne (1853), B. von Langenbeck (1888), and C. Parkhill (1897) [cited according to 7, 15, 16, 20, 26, 30, 36]. Albin Lambotte (1907) [20] from Belgium was the first to report on the systematical application of an external clamp fixator forceps.

The regular use of external fixators for fracture treatment in the mandible began during World War II with a universal instrumentation adopted from veterinary medicine (small animal surgery—Otto Stader) and surgery of extremities (Roger Anderson).

Those equipments were regarded and criticized as bulky, awkward, too heavy, mechanically unreliable, and unhygienic and were soon amended in construction and size with better fit to the dimensions of the mandible [30, 32] (survey in [41]). The procedure was dubbed as ‘pin fixation’ [37]. A common feature of all appliances of that time was the unilateral assembly along the lateral plane of the mandible and the modular technique. A set of at least two pins was inserted into each main fragment and attached by means of pin-to-rod connectors to an embracing external metal rod, thus building up a subunit or rather a module. After reduction of the single modules, a connection rod (via rod-to-rod clamp appliances) was put up for bridging the subunits and construct an overall frame.

The appliance of Converse and Waknitz [7] (Case Report 1942), oftentimes cited as ‘Frac-Sure-Appliance’, was based on the same principle. The last version of this device was made up of two convergent Kirschner wires that were interconnected over miniaturized ‘pin blocks’ and coupled to universal articulations. These articulations were adjustable in all directions and gliding on a metal bar. This mechanical system was reported to have accounted for a very precise reduction of the fragments.

The ‘biphase connector’ of Morris [28, 29] was an interesting fixator variation. In the primary treatment phase, a three-dimensionally adjustable mechanical holding frame, composed of a metal rod with special clamps and universal articulations, was attached to the shafts of the percutaneous screws next to the fracture in order to splint the fragments. In the second phase, all screw heads were blocked with a plastic bar made from an autopolymerizing dental acrylic and the mechanical frame was removed after thermosetting. The acrylic compound offered the particular advantage to mold the bar while in the plastic state with the chance for a less bulky and smooth design. The acrylic material was radiolucent and low priced. Finally, the primary metal reduction splint was reusable.

From the postwar period to the early 1970s, the external fixator gained widespread use as one of the first methods for a surgical treatment of mandible fractures (e.g., Ginestet [15], Ullik [38], Mathis [26], Schüle [35], Gillies and Millard [14], Becker [3], Frenkel [12], Birke [5], Gabka [13], and MacIntosh [24]). The indication for external fixation was limited to fractures that were difficult to address with the intraoral arch bars, prosthetic, or gunning splints regularly in use at that time: displaced fractures in the edentulous mandible or in the posterior mandibular subunits with no dentition (mandibular angle/ascending ramus), heavy comminution and defect situations, as well as pathologic fractures.

The construction of pin fixation devices known so far was modified thereupon by some authors, but the basic idea of a single plane (uniplanar) construction encompassed by metal frame or a synthetic shield (e.g., Becker splint) was usually paraphrased. A polygonal fixator design [2] with anchoring screws in two lines positioned at the basal border and along the lateral surface of the mandible, then cross-barred in space to each other, resulted in higher stability than the previous concepts. Although due to the high risk for inferior alveolar nerve lesions and its oversized proportions, this device never became generally accepted.

It took quite long up to the middle of the 1980s until a number of new publications on external mandibular stabilization devices constituted of steel rods appeared [6, 19, 22, 31, 36, 43].

Among those, the “clamp fixator mandible type” as developed by Spiessl [36] on the basis of the AO hand fixator system had a comparatively simple design. This fixator was made up of only three assembly parts: preformed metal rods, Schanz screws, and clamps to fasten the screws to the rods. The same components are found again in the present ‘external mandible fixator’ in an even more simplified design.

In the early 1990s, surgical treatment methods for subcondylar mandible fractures became more accepted and a semi-rigid titanium mini-fixator for the external

treatment of the condylar process [18] was presented. A case report has just recently appeared on this topic [34].

Apart from fracture treatment, external fixator appliances are suitable to maintain the jaw relationships in continuity resections of the mandible. The resected bone segment is bridged and the residual stumps are kept in their original position. The use of an external metal or synthetic framework designed for such bridging— intraoperative for a primary or temporarily up to a second-stage reconstruction—has often been described [1, 4, 11, 21, 23, 25, 36, 42].

The history of distraction osteogenesis in the mandible with external fixator devices is not considered in this short review (survey in [9]), though the tremendous popularity of this procedure around the turn of the millennium might have paved the way for a comeback of external mandible appliances utilized for osteosynthesis under difficult circumstances and for defect bridging.

It is noteworthy that the ‘biphase connector’, meanwhile known by the inventor’s proper name as ‘Joe Hall Morris external fixation device’, has ever since been used with unmodified design in the Anglo-American world (see, e.g., [10, 27]). It is still available on the market now equipped with titanium screws (Lorenz Bi-phase™, Biomet Jacksonville, FL, USA).

## Materials and methods

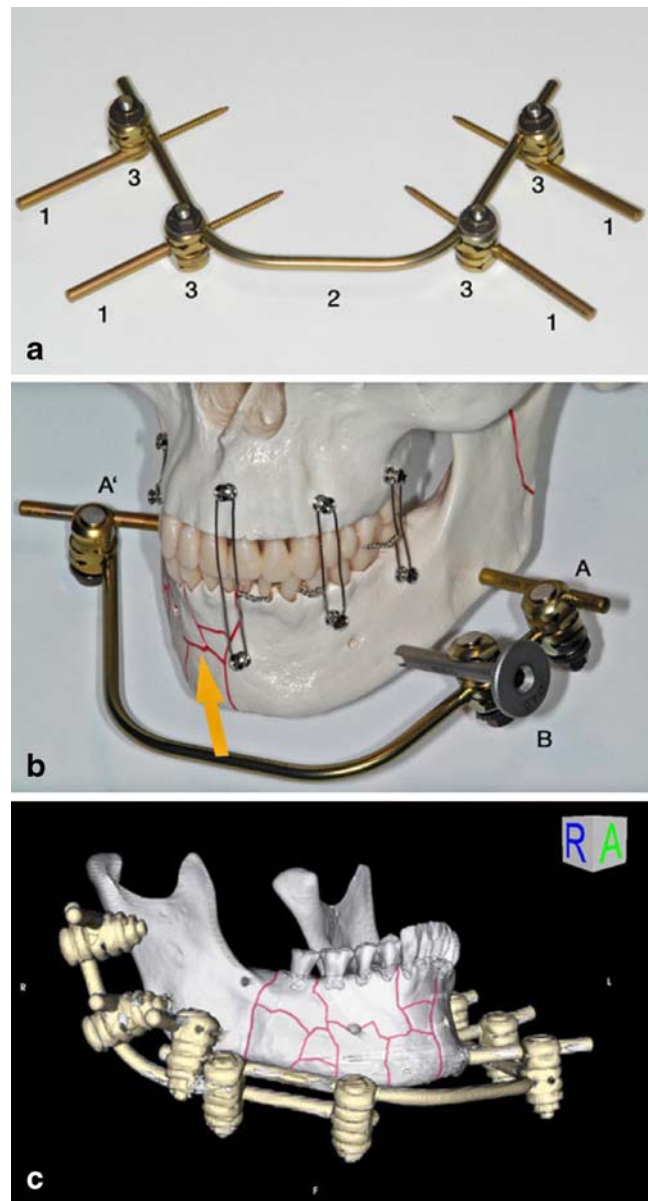
Mandible external fixator: basic components, instrumentation, and application technique

The mandible external fixator set (Synthes) consists of the following basic elements (Fig. 1a):

- Pins and Schanz screws (titanium) self-drilling or self-tapping (diameter, 2.5 mm/4.0 mm; extension 50/60/70/80 mm) for percutaneous application;
- Connecting bars: pre-bent rods (titanium; diameter, 4.0 mm) to the shape of the mandible in incremental anatomical partitions: a half mandibular body, a three-quarter mandibular body, a full semicircle mandibular body, and a full semicircle mandible including the ascending rami;
- Adjustable combination clamps with snap-on mechanism (titanium) that are attachable and self-holding for linkage of Schanz screws/Kirschner wires and rods for the frame construction.

Snap-on clamps feature two pairs of laterally open gripping slots with an oval groove–recess on each side.

A spring is set between the two pairs of gripping slots aligned on a bolting screw. The groove–recesses inside the



**Fig. 1** **a** Framework of the ‘mandible external fixator’ (Synthes Maxillofacial®, Paoli USA) consisting of three basic components: 1 pins or Schanz screws (type self-tapping), 2 connecting rod, full semicircle mandibular body, 3 adjustable snap-on clamps for connection between 1 and 2. **b** ‘Visor style’ technique (model). The montage of the external fixator is accomplished after reduction of the main fragments and maxillo-mandibular fixation. Two pins in terminal position at the mandibular angle (*A* or *A'*) form a hinge axis for the clamped on semicircular mandible rod (monofixator) that is adjusted to level of the mandibular base (*arrow*). A transbuccal trocar (*B*) is fixed to the semicircular rod with a clamp for a targeted insertion of further screws in proximity to the fracture zone. **c** Color marked 3D CT scan of the model mandible from Fig. 3 with total fixator setup verifying the imaging compatibility. The semicircular full mandibular body rod is backed up with additional Schanz screws and a double-stacked rod to increase the stability of the framework

slots are asymmetric in size for engaging metal rods of either 4.0- or 2.5-mm diameter. A counter nut fixes the slot pairs against each other in any rotational position, producing a stable connection between the rod and pin or Schanz screw.

Prior to the application of the external fixator, the main fragments or main segments get immobilized by a rigid maxillo-mandibular fixation (e.g., MMF-screws and inter-maxillary wire ligatures).

The pins or Schanz screws are inserted with a trans-buccal handle. Trocar drill guides are placed in the handle to protect the tissue; the different lengths of the drill guides are selected according to the thickness of the soft tissue layer and the predefined pin length.

The basal lateral surface of the mandible caudal to the mandibular canal is the best suited area for insertion of the Schanz screws. Preferentially, the screws are set bicortically in an orthogonal direction to the bone surface.

Depending on the bone quality and fragment size, the Schanz screws can be inserted manually with a handle after pre-drilling and length measuring (self-tapping screw type) or automatically (self-drilling screw type) using a Jakob chuck at low speed.

It is recommended by the manufacturer to assemble the different basic components named above in the manner of a ‘monofixator’ or in a ‘visor-style technique’, respectively.

After stab incision and blunt preparation of soft tissue tracks down to the periosteum, the first two screws are inserted. The screws are positioned into the intact mandibular remnants on opposite sides of the fracture or defect area as distant from the damaged zone as possible. The placement of these two terminal screws must be kept in line with the end pieces of the previously contoured titanium rod.

The rod ends are then connected to the two terminal screws via the snap-on clamps.

In case of using a full semicircular connection rod clamped on the terminal screws in each mandibular angle, the basic assembly resembles a “visor” on a helmet (Fig. 1b). With the clamps loosely tightened, the visor can be lifted or shut down around this hinge axis.

The insertion of the subsequent pins follows in the direction towards the fracture or defect area.

The pin placement is predetermined by the position and curvature of the circular rod, setting clear limits to any free choice arrangement.

The snap-on clamps are employed as a targeting device for the insertion of the inner pins near the fracture or defect.

The clamps are fixed to the circular rod using one pair of the gripping slots. The second pair of slots is turned into a position so that the grooved recess shows onto the skin surface, thus serving as a marker for the stab incision. Thereafter, the transbuccal trocar is locked inside and adjusted to allow for a pin insertion in parallel with the terminal screws.

For the bridging of short (4–5 cm) mandibular sections, two percutaneous Schanz screws on each side of the whole external fixator framework provide sufficient stability. A maxillo-mandibular fixation is unnecessary and by the way would contradict the intention of the mandible external fixator system.

Extensive defects with a long span of the fixator require the insertion of additional screws and connection elements. If necessary, the monoframe is complemented with backup rods in a double-stacked array or in an outrigger fashion (Fig. 1c).

A recent upgrade of the mandible external fixator product line (phase II) is offering a number of refined components for modular use.

These modular components were not applied for the reported patient series. Nonetheless, these parts are listed hereafter, as in the future, they will allow fixator assemblies with an extended therapeutic range:

- Carbon rods (diameter, 4.0 mm; lengths, 60/80/100 mm);
- Kirschner wires with thread (diameter, 2.0 and 2.5 mm; length, 150 mm; thread length, 15 mm); and
- Parallel pin clamps: snap-on clamps with a pair of symmetric slots to hold two rods with identical diameter (2.0 and 2.5 mm) designed for parallel insertion of two Kirschner wires in smaller fragments.

Wherever realizable, we applied well-established biomechanical principles [16, 36] to ensure the peak framework rigidity of the external fixators.

This meant:

- Exclusive application of large diameter (4.0 mm) pins or Schanz screws, respectively;
- Insertion of the inner pins in close proximity (approximately 1 cm) to the fracture/defect area and at the maximal (intra-fragmentary) distance to the outer (terminal) Schanz screws; and
- Assembly of the connecting rods near above the skin surface (approximately 1.5 to 2 cm) to minimize the free length of the pins between the load bearing frame and the bony surface.

## Indications

The indications for use of the external fixator in our series were based on the recommendations by Schüle [35], Frenkel [35], and Spiessl [36] with the following selection:

- pathological mandible fractures in infected osteoradionecrosis, tumors, osteomyelitis, or large cyst formations;

- heavy comminution, defect, or gunshot fractures with extensive soft tissue damages (open/infected—perforations, penetrations, avulsions);
- bridging of (resection-)defects until secondary reconstructions; and
- emergency care of open fractures in polytrauma cases.

Fractures of the non-tooth-bearing mandibular angle and in the edentulous (highly) atrophic mandible as well known from the historical review on external fixator applications were excluded.

#### Patients

During the affiliation of the authors at the German Armed Forces Hospital in Ulm between March 2005 and November 2006, the mandible external fixator was used for treatment in a total of ten patients (all male aged between 39 and 73 years, mean 55 years). In eight cases (Table 1), the fixator was applied in the course of a head and neck tumor therapy and in two patients (Table 2) for treatment of mandible fractures with polytrauma. The concept for the use of the mandible external fixator was a simple and immediate functional repair of mandibular continuity without need for intermaxillary fixation and avoidance of a major surgical approach associated with additional soft tissue impairment.

#### Results

Details on the medical history of the patients, indication for treatment and results are recorded in Tables 1 and 2.

In three oncological cases (Table 1, patient nos. 3, 4, and 6), the external fixator was used for palliation in mandibular defect situations (osteoradionecrosis, pathological fracture or resection, orocutaneous fistula). In one of these patients (Table 1, patient no. 4), the cheek and the hemitongue, as well as the anterolateral mandibular body on the right side, were resected with initial curative intention after unsuccessful pretreatment of multiple recurrences of a floor of the mouth carcinoma. The fixator was installed to bridge the bony defect and the soft tissues were packed. At the outset, it was planned to use the appliance for a temporary period until a reconstruction could be completed after the report of definite histological results. Due to rapid tumor progression, three further attempts to achieve free margins of the excessive tumor spread into the soft tissues (root of tongue, contralateral floor the mouth) and the mandibular ends with removal and remontage of the external fixator ended frustratingly.

In a subgroup of five other tumor patients (Table 1, patient nos. 1, 2, 5, 7, and 8), the external fixator was

applied during secondary curative management. In all these cases, the patients had been exposed to previous irradiation therapy for primary care. In periods ranging from 8 months to 16 years, pathological fractures had occurred and an infected osteoradionecrosis with cutaneous, orocutaneous, or mucosal fistula was present. Besides, a residual tumor was found in one of the patients (Table 1, patient no. 2, case report 1) that was amenable to an in toto resection.

The pins, the snap on clamps, and the connecting rod system in all the above cases were set up using the visor technique directly after wound debridement and taking excisional biopsies. The pins next to the fracture or defect were positioned at a suitable distance to ensure stability and give potential yield for further resection of the bone stumps. Since there were two fragments only, closed reduction and realignment was no particular issue even with remaining dentition and the necessity for the provision of a correct occlusion. Wherever appropriate, the patients were put into a temporary maxillo-mandibular fixation by means of transmucous cortical bone screws and wire ligatures.

After maintenance of the skeletal relations with external fixation over periods between 40 and 174 days in the curative tumor subgroup, the surgical therapy proceeded as follows:

In two patients (Table 1, patient nos. 1 and 8), the fistulae had healed completely during immobilization and the fracture/defect area was bridged with an angle-stable reconstruction plate, i.e., external fixation was replaced with a locking plate acting as an internal fixator. In three cases, the mandibular defects were filled with revascularized bone grafts [Table 1, patient no. 2—lateral scapular border bone flap, patient no. 5 (=case report 2), and patients no.7—osteo-fascio-cutaneous fibula flaps], which were likewise fixed with Locking reconstruction plates.

The two polytraumatized patients (Table 2) had panfacial fractures. In both cases, the mandible external fixator was used for primary treatment of the mandible. The first trauma case had extensive soft tissue lacerations in the lower lip in combination with an open multiple-piece paramedian fracture on the right side. After reduction, the exposed fragments were adapted with mini-plates and the soft tissues meticulously closed. Instead of a load-bearing internal plate requiring a wound extension, the overall stability was secured with a supplementary full arch external fixator framework with pin location along the mandibular angles. Open reduction and osteosynthesis of the midface and frontobasal fractures was effected at a later stage. With the patient's agreement, the external fixator remained in the mandible for more than 6 weeks without a procedural change towards complete internal fixation until osseous consolidation of the fracture area occurred.

In the second trauma patient, however, a severe malposition after an attempt to align the comminuted mandible fragments in closed reduction necessitated a

**Table 1** Survey—Tumor patient collective (total  $n=8$ ) treated with mandible external fixator—consecutive series

Pat-ient/ Age	Underlying Disease	Initial Dia- gnosis	History / (Dentition)	OMF Diagnosis on Admission	Indication for External Mandible Fixator (Pin Pattern)	Ex Fix in situ Period / Pin track - Infection - Loosening	Further Treatment Measures/ Outcome
1 BR 57 ys	SCC tongue base right T2N1M0	3 years previ- ously	laser resection tongue base / epiglottis, post OP irradiation (edentulous)	pathologic fracture mandibular angle - right, orocutaneous fistula, infected ORN	stabilization (2 – 2 pins), débridement, wound conditioning	100 days/ none	subsequent to healing of fistula, changeover to internal reconstruction plate, no bone grafting
2 EW 69 ys	intermaxillar y SCC left T2N0CM0	8 months previ- ously	tumor resection, postOP irradiation (partial dentition)	pathologic fracture mandibular angle - left, mucosal defect, exposed bone, infected ORN, local tumor recurrence	stabilization (2 – 2 pins), débridement, HBO: 15 dives, resection, wound conditioning	111 days/ none	after 2 reresections and mucosal healing SOHND and bone reconstruction (bone flap from lateral scapular border + bridging plate)
3 GH 55 ys	SCC anterolateral floor of mouth left T4N3Mx	2,5 years previ- ously	surgery refused, primary irradiation (80 Gy) (edentulous)	pathologic fracture mandibular body - left, orocutaneous fistula, infected ORN, tumor progression, cachexia	stabilization (2 – 2 pins), débridement, palliation	23 days/ none	acute multi- organ failure, renal and liver (cirrhosis) failure, exitus letalis
4 KH 49 ys	SCC anterolateral floor of mouth right, cheek right T2N0Mx	3,2 years previ- ously	laser resection, irradiation, multiple small recurrences and reresections in the course of 2,5 years (partial dentition)	residual tumor, recurrence	stabilization (3 – 3 pins) salvage surgery: several additional resections incl. mandibular segments, ND and leaving defect	157 days/ none	all reresections frustraneous, tumor progression, distant metastasis, exitus letalis
5 Sch R 58 ys	Epipharyn- geal SCC T2NM0	16 years previ- ously	primary irradiation, lymph node recurrence - cervical metastasis right, ND, carotid endarterectomy right, safety coverge with upper trapezius flap, recurrent exacerbations of ORN (edentulous)	pathologic fracture mandibular angle - right, orocutaneous fistula, infected ORN	stabilization (3 – 2 pins), débridement, wound conditioning	70 days / none	subsequent to healing of fistula mandibular reconstruction (osteofascio- cutaneous fibula flap and reconstruction plate), recipient vessels left neck

**Table 1** (continued)

6	SA 66ys	SCC sublingual sulcus, floor of mouth right T1N1M0	2,9 years previ- ously	tumor resection, ND, postOP irradiation, local recurrence - marginal mandibular (rim) resection, chemotherapy (edentulous)	pathologic fracture mandibular body right, orocutaneous fistula, infected ORN, extended local recurrence	stabilization (2 – 2 pins), woundcare, palliation	123 days/ none	no resectability, tumor progression, distant metastasis, exitus letalis
7	BE 38 ys	SCC anterolateral floor of mouth bilateral T2N1M0	2,9 years previ- ously	tumor resection, marginal mandibular resection (rim) region 35 - 44, SOHND bilateral, postOP irradiation (60 Gy), osseous dental implants in rim resected portion	pathologic fracture paramedian mandible right, infected ORN, periimplantitis, loosening of implants	stabilization (2 – 2 pins), wound conditioning subsequent to implant removal	40 days/ none	after healing of fistula mandibular reconstruction (osteofascio- cutaneous fibula flap and reconstruction- plate)
8	SchJ 45 ys	T-ALL, cervicale manifestatio n right	12 years previ- ously	combined radio- chemotherapy, irradiation of neck and thorax, multiply recurrent infections of sub- and paramandibular spaces (partial dentition)	pathologic fracture mandibular body right, infected ORN, cutaneous fistula	stabilization (2 – 2 pins), débridement, wound conditioning	174 days/ none	after healing of fistula conversion to internal reconstruction plate (bridging soft callus formation of fracture zone)

Palliative case group (*n*=3) highlighted in blue.

SCC squamous cell carcinoma, ORN osteoradionecrosis, ND neck dissection, SOHND supraomohyoidal neck dissection, HBO hyperbaric oxygen therapy, T-ALL T cell acute lymphoblastic leukemia

conversion to internal fracture treatment within a few days (see case report 3).

In the whole patient collective, the surgical time for pin insertion and application of the external fixator ranged between 20 and 35 min. The pin insertion could invariably be accomplished in an atraumatic fashion. All pins were bicortically inserted and proved primary stability. The penetration channels through the skin showed no infection or inflammation.

The downtime with the external mandible fixator in situ amounted up to 174 days (mean, 75 days) within the whole patient collective. During these periods, loosening of Schanz screws and/or so-called pin track infection was not observed even after long duration. Saliva fistulas after pin insertion through the parotid gland did not occur.

Mechanical problems originating from the clamps or rods and leading to dislocation of the mandibular divisions was not noted either.

Unexpectedly, the patients did not feel all too bothered from the external framework. They changed their sleeping habits to laying their head opposite to the device or on the occiput. Shaving, skin and pin care had to be done with the assistance of family members or nurses.

After removal of the pins, minor scarring and contractions developed in the skin, but this was never disapproved by any of the patients.

**Case reports**

Case 1

Patient E.W. (age 68 years, male; Table 1, patient no. 2; Fig. 2): First consultation for left mandibular angle fracture with extensive mucosal defect and exposed bone. Medical history: status after inter-maxillary squamous cell carcinoma on the left (TMN), initial diagnosis and tumor resection

**Table 2** Survey—Polytrauma patients ( $n=2$ ) treated with the mandible external fixator

Patient/age	Underlying disease	History	OMF diagnosis on admission	Indication for external mandible fixator (pin pattern)	Ex fix in situ period/pin track (infection, loosening)	Further treatment measures/outcome
1 Sch/G/53 years	Polytrauma, head trauma	Bicycle fall	Panfacial trauma, frontal skull base fracture, Le Fort I,II,III fractures, mandible multi piece-fracture parasymphyseal left, laceration of chin, penetration of lower lip (partial dentition)	Initial stabilization and bridging of fracture zone (2–2 pins) in combination with miniplates	42 days/none	Subsequent internal fixation of midface and frontal skull base fractures, fracture healing of the mandible under load bearing by external fixator
2 AY/39 years	Polytrauma	Rear impact car crash	Panfacial trauma, Le Fort I,II,III fractures, palatal fractures multifragmentation of whole mandible, multiple tooth injuries and loss, crown fractures	Initial stabilization of main fragments (3–2 pins) to stop hemorrhage and for controlled intraoral soft tissue repair	7 days	Definitive treatment, conversion to internal fixation of mandible and midface

ER emergency room

elsewhere 7 months ago, status after radiotherapy completed 4 months ago. Admission diagnosis: pathological mandibular angle fracture with intraoral fistula due to infected osteoradionecrosis and sequestration. Comorbidity: Parkinson's disease.

In this defect situation with undefined histology, a stabilization of the right hemi-mandible was acquired using the mandible external fixator set (half mandibular body connecting rod). A decortication and a soft tissue excision around the stumps were carried out. By way of precaution, the percutaneous pins (Schanz screws, 60 mm-length, 2×2 pin arrangement) were inserted at some distance of the defect zone.

In addition to antibiotic administration, the patient underwent hyperbaric oxygen therapy postoperatively. The histologic examination confirmed osteoradionecrosis but showed remnants of a squamous cell carcinoma.

Subsequently, 2 weeks later, the bony stumps and the surrounding soft tissues were resected once more with intraoperative control of frozen sections of the mucosal margins. The definitive histology still detected tumor infiltration within the osseous margins (R1 resection).

The patient temporarily left the hospital with the fixator in situ. Two weeks later, another resection was done, eventually with a R0 result.

In the following 3 months, with external stabilization of the mandible, the inflammation subsided and the mucosal lining regenerated to complete closure of the soft tissue defect.

Pin infection or loosening did not occur. After a preoperative digital subtraction angiography of the left subscapular vascular axis, a left supraomohyoid neck dissection was performed (SOHND  $\approx$  AJCC levels I, II, and III) and the external fixation was converted to rigid internal fixation with a reconstruction plate (2.4 UniLock, Synthes).

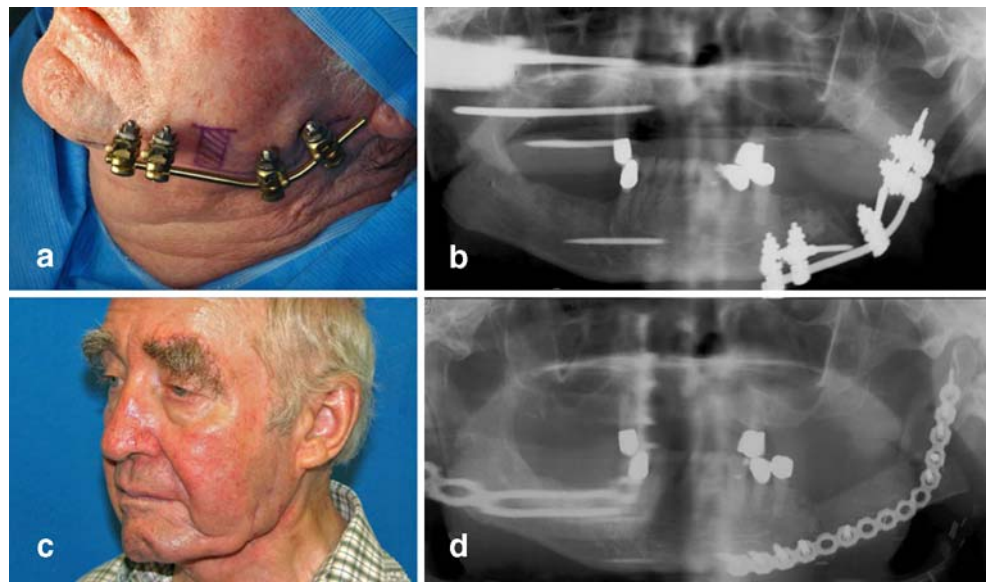
The osseous stumps were cut back once more and a coronoidectomy on the left was done. The mandibular bone continuity was then restored with a revascularized myosseous graft from the left lateral scapular border. The inner mucosal lining in the defect area was left intact during the reconstruction procedure. The postoperative course was uneventful.

## Case 2

Patient Sch.R. (age 68 years, male; Table 1, patient no. 6; Fig. 3): Hospitalization due to infected osteoradionecrosis with a pathological fracture in the right mandible angle combined with intra-extra-oral fistula. Medical history: Epipharyngeal carcinoma 16 years ago, status after primary irradiation, status after endarterectomy and vein patch of the common carotid artery on the right because of stenosis. Safety coverage of the neck vessels with an upper trapezius



**Fig. 2** Case 1: **a** Mandible external fixator assembly over left mandible (pin setup 2×2) in a pathological fracture after irradiation and tumor recurrence. The site of the osseous defect is sketched. **b** Panoramic X-ray showing the full bony defect size after achieving free margins following two further resections of the osseous stumps (R0). **c** Oblique facial view 15 months after mandible reconstruction. **d** Panoramic X-ray after mandibular reconstruction: revascularized bone graft from left lateral scapula border, fixation with reconstruction plate. Note coronoidectomy on the left



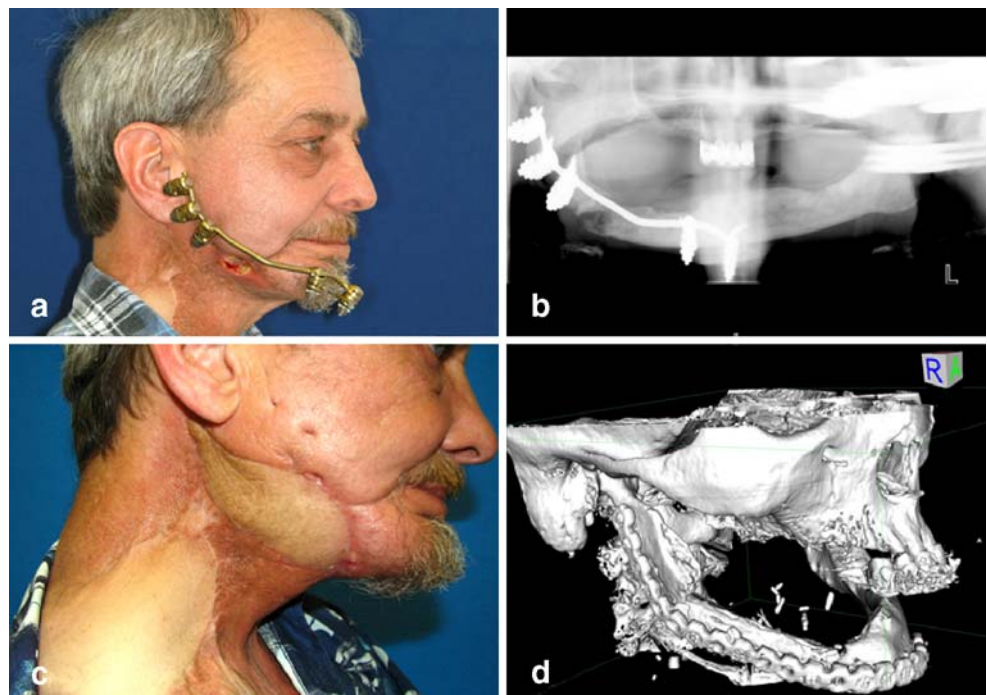
flap 15 years ago. Hospital treatment for osteoradionecrosis of right mandibular body 8 and 4 years ago at last.

As initial treatment, a sequestrotomy in the fracture area was done bridging the defect with an external fixator (Schanz screws: length 60 mm, 2×2 pin pattern in combination with half mandibular body connecting rod). Soft tissue margins were taken followed by open packing.

On the sixth postoperative day, the patient was discharged for follow-up treatment by an office-based CMF surgeon near home.

After an in situ period of 2.5 months without pin track infection or loosening, the osseous stumps were freshened up, a coronoidectomy performed, and the compound defect closed with an osteo-fascio-cutaneous fibula graft, which was fixed with a reconstruction plate (2.4 UniLock, Synthes). There was no reentry into the midneck on the right. Flap revascularization was done by end-to-end anastomoses to the superior thyroid vessels on the contralateral (left) neck. There was prolonged wound healing over 3 months with secondary granulation over the graft surface intraorally and along the borders of the external skin island.

**Fig. 3** Case 2: **a** Mandible external fixator assembly (pin setup 3×2) bridging pathological fracture in the right mandibular angle, oro-cutaneous fistula. **b** Panoramic X-ray after pin fixation. **c** Semi-profile showing the skin island of the osteo-fascio-cutaneous fibula flap overlying the mandibular border. A superior trapezius flap covers the posterior cervical triangle, previously transposed for protection of the neck vessels after carotid endarterectomy. **d** 3D CT scan 8 months after reconstruction: Fibula flap restoring bone continuity of the right mandible in conjunction with reconstruction plate. Note coronoidectomy on the right



## Case 3

Patient A.Y. (age, 39 years, male; Table 2, patient no. 10; Figs. 4 and 5): History: High speed rear-impact car crash accident (speed approximately 60 km/h), safety belt not attached; emergency primary care on accident site, intubation, artificial respiration, sedation, Foley catheters as posterior nasal packing (modified Bellocque style) helicopter transfer into ER. Initial diagnosis: polytrauma with bilateral pneumothorax, splenic rupture, multiple fractures of the lower extremities, Maxillofacial findings: panfacial fracture: all Le-Fort levels, multiple palatal fragments, naso-orbito-ethmoidal fractures bilateral Markowitz type III, teeth loss in the maxillary front, multiple tooth crown fractures in mandible and maxilla, multifragmentation over all mandibular subunits. Persistent hemorrhage from the oral cavity was maintained by multiple mucosal tearings over the alveolar process and diffuse from the floor of the mouth. As an urgent measure, dense packing of the oropharyngeal tract and tracheostomy were done.

Since cardiopulmonary instability did not allow for extended surgery with accurate fragment reduction, fixation of dental arch bars, etc., the greater pieces of the mandible were stabilized with an external fixator (Schanz screws: length 60 mm, 3×2 setup in main fragments—full semicircle mandible body connecting rod) using the visor style technique (Fig. 4).

Starting with percutaneous screw placement in the mandibular angles and mounting the connecting rod, a controlla-

ble alignment of the distal fragments could not be realized and was done in a provisional manner. The enoral wounds were sutured after removal of the packing material, and despite osseous malposition, a sufficient hemostasis was reached.

The definite surgical care of the panfacial fractures followed 7 days later in a typical sequence with conversion to internal fixation in the mandible with lag screws and plate osteosynthesis (Fig. 5).

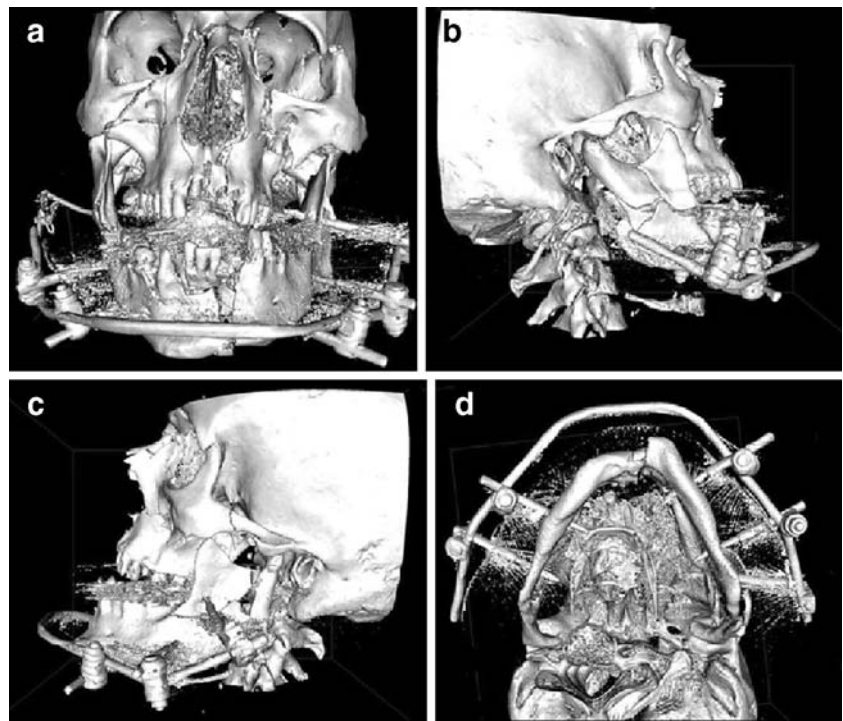
## Discussion

The mandible external fixator corresponds to the Joe Hall Morris appliance, which is rarely used in Central Europe. It represents a modular assembly kit for pin fixation of the mandible and excels with a simple, quick, and atraumatic handling. Just like in any other external fixator, the framework is made up of skin-penetrating anchors (pins or Schanz screws, respectively) that are linked to the circumferential rods with snap-on combination clamps.

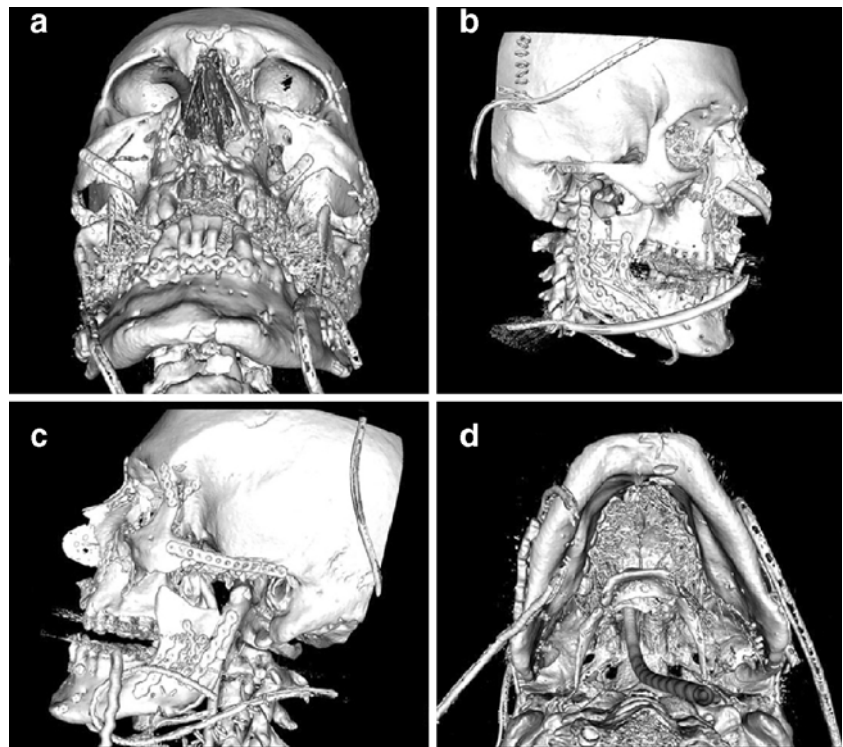
Subsequent to montage and securement of the connecting rods, an external fixator in principle is angle-stable and must be appraised as the antecedent conception of the angle-stable internal plating systems nowadays in use.

The stiffness and biomechanics of external fixation systems in the human mandible have been only marginally examined so far [2, 35, 36]. In contrast, pin fixation in the dog mandible has been studied in depth (example [8]), but the results are not transferable to humans owing to obvious

**Fig. 4** Case 3: Application of the mandible external fixator in a ‘visor style technique’ for immediate care in multifragmentation resulting in malposition and misalignment of the fragments. Although the framework fulfilled its purpose to stop the bleeding in this fortunate case by stabilization of the major fragments, a montage in ‘modular technique’ is preferable because of its versatility (for details, see “Discussion”). **a** 3D CT full face frontal view. **b** 3D CT right profile view. **c** 3D CT left profile view. **d** 3D CT basal view



**Fig. 5** Case 3: Conversion to internal rigid fixation 7 days after emergency treatment with the mandible external fixator. Aside from the mandible (lag screw osteosynthesis in the symphysis), the midface was repaired. Immediate postoperative imaging control with all tubes in place. **a** 3D CT full face lower frontal view. **b** 3D CT right profile view. **c** 3D CT left profile view. **d** 3D CT basal view



discrepancies in the morphology of the mandibular curvature, the masticatory action (chopping instead of chewing), and the biting loads.

Despite the lack of a valid data background, the mandible external fixator appears pertinent for a load-bearing osteosynthesis from its dimensioning and material properties [33].

The osteosynthesis with an external fixator in the mandible is still limited to exceptional cases [36, 41–43]. Justifiable indications are given in fracture or defect situations aggravated by diminished bone quality and/or critical soft tissue conditions:

- in pathological mandible fractures, most of all ensuing irradiation and thus associated with infected osteoradionecrosis, or after gross tumor infiltration, osteomyelitis, or extensive cysts;
- in comminuted fracture zones or bone defects that are combined with lacerations, avulsion, or significant loss of the soft tissue envelope, compromised wound healing, problematic vascularization, or unpredictable soft tissue necrosis in the initial management of severe gunshot or blast-related injuries or after third-degree facial burns or voltage injuries.

The external stabilization of the mandible in polytraumatic cases is a rapid emergency procedure, while definite repair can be deferred for a later phase of care. The conversion from external pin fixation to internal fixation

will facilitate the comprehension and exact alignment of all the bony pieces in multifragmentation and is considered the protocol of choice for definite treatment. Besides, rigid internal fixation will shorten the treatment period.

The insertion of the Schanz screws is relatively harmless, since the percutaneous undermining of the soft tissues is confined to a narrow space in a distance to the fracture or defect zone. There is no need for major surgical incisions in the submental, sub- or retromandibular region and for periosteal elevation over the bone adjacent to the lesion, as necessary for the anchoring of reconstruction plates.

All eight tumor patients of our series had undergone radiation therapy. No healing difficulties or signs of infection occurred in the soft tissue sleeves around the Schanz screws in any of these cases.

After immobilization of the fragments, two patients of this group (Table 2, nos. 1 and 8) showed spontaneous closure of their fistulas and a soft tissue consolidation, allowing for a conversion from the external fixator to a reconstruction plate obviating a concomitant soft tissue coverage.

In preparation to the pin insertion, it is crucial to reduce the main fragments and secure them against dislocation—manually or whenever appropriate through maxillo-mandibular fixation (Fig. 1b).

If the fixator framework is assembled in the ‘visor style technique’, it is mandatory to begin the sequence with the alignment of the fragments because the pre-contoured, single-piece full circular connecting rod once fixed to the

mandibular angles will restrict the options for the placing of successive screws exclusively along the pathways of the ‘monofixator’ frame.

With all of the pins randomly inserted in unreduced fragments from the start of the procedure, some adjustment may be possible relying on the clamp mechanics, albeit to a low extent. Mostly, the congruity among the pin position and the inflexible connecting rod framework will be lost soon.

When a defined defect area (Table 1, patient nos. 1–8) or a singular comminuted zone (Table 2, patient no. 1) is being bridged, the adjacent major mandibular divisions are usually easily reducible beforehand so that the ‘visor style montage’ of the mandible external fixator is not posing a serious problem.

In multifragmentation encompassing several mandibular subunits, a montage in a ‘modular technique’ is strongly encouraged, since rebuilding the overall mandibular ensemble ‘discontinuously’ out of prefixed partitions offers more degrees of freedom. Hence, the pin placement sites in every subunit can be selected rather generously. Two pins in each fragment are joined with short connecting rods to form a module and serve as a handle for the reduction. These modules are subsequently aligned and braced three-dimensionally with intermediate rods (rod-to-rod) until completion of a setup, which takes in all larger fragments. Such a setup, however, has the disadvantage to carry a high number of construction elements in parallel line with oversize and high overall weight.

Case 3 (Table 2, patient no. 2; Fig. 4a–d) demonstrates the limitations of the reduction utilizing the ‘visor style technique’ in the immediate care of multifragmentation involving all topographic divisions of the mandible. Further treatment could have been provided through modification into a modular montage with secondary reduction of all fragments.

The first product line of the external mandible fixator, though, did not offer the components necessary for this procedure. The prospect of a controlled open reduction with accurate alignment of all major and minor mandibular fragments in a sequential fashion in reference to the reduced maxilla and midface, however, was regarded crucial for a treatment conversion to internal fixation techniques.

Extremity surgery has known difficulties in fragment reduction with the use of monofixators for a long time [16, 39].

Concerning the facial skeleton, Waldron (1943) [4] was among the first to criticize the limited options for reduction with some of the former mandibular pin fixation systems because the construction elements were not versatile enough.

To secure exactly reduced fragments, it seems ideal to block the pins with an autopolymer. The pin array can be joined with the synthetic material in the ‘biphase’ manner

or, following a more recent suggestion [42], in a ‘monophase’ way.

For the ‘monophase’ fixation, a reinforcing silastic tube or an endotracheal tube with corresponding perforations is put over the pins and injected with the liquid autopolymer.

In complex fracture patterns, in particular in extensive multifragmentation, both modes become unpracticable, since the overall assembly requires either splinting with various adjustable mechanical frames or numerous helping hands at a time to maintain all pieces in position.

External fixator appliances can stay in situ in the mandible for months [4, 11, 15, 24, 36, 42] (example Table 1, patient nos. 4 and 8). Pin track infections and pin loosening or mechanical problems in the rod systems did not occur in any of our patients.

The external fixation is suitable as a load-bearing supplement to internal fixation with miniplates until the osseous consolidation has completed (see Table 2, patient no. 1).

A long-term application of external mandible fixators is especially helpful in palliative and curative tumor therapy. The definitive results of histological margins and bone specimens can be awaited.

Further resections become possible. If needed, pins can be removed to allow for enlarged resections and repositioned after building up the frame construction with outrigger rods (see Fig. 3).

Prior to final reconstruction, e.g., with free bone grafting techniques [17] or a revascularized tissue transfer, the mandible external fixator allows for reexamination with all types of imaging techniques.

The titanium alloy of pins, clamps, and connection rods does not induce artifacts in CT scans (Fig. 1c) and is MR safe. These imaging characteristics are one of the reasons why titanium-made external fixator systems are used by coalition troops for primary stabilization of the mandible defects in polytraumatized soldiers and civilians after acts of terrorism or combat operations.

The US Army field centers in Iraq classify the external midface fixators as “combat medical device” (<http://www.cbsnews.com/sections/ivideo/main500251.shtml?id=2135920n>). This term paraphrases the particular suitability of the systems for the immediate care under time pressure in direct vicinity of a battlefield. The potential relevance of the mandible external fixator was the central motive to enter into this clinical series during our affiliation at the German Armed Forces Hospital, fortunately under peaceful conditions and with a divergent scope of indications.

## Conclusions

Our experiences show that external pin fixation of the mandible is a valuable treatment option to bridge localized

comminuted fracture areas or defects that are associated with compromised bone quality and/or a critical soft tissue situation. This constellation is prevailing in pathological fractures after treatment of head and neck tumors including irradiation or gunshots. No major incisions for the surgical approach are required for the fixation. The stabilization of fragments or resection stumps can be rapidly and reliably achieved.

In polytraumatized patients, the external pin fixation of the mandible is an appropriate emergency method with a low complication rate. The mode of application and the reduction procedure have to account for the fracture pattern over the entire topography of the mandible. Far-spread multifragmentation is a caveat to use a ‘visor style montage’.

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