Fractures of the severely atrophic mandible can occur following trauma, peri-implantitis, or explantation.1–4 Patients with fractures of the atrophic mandible are generally older and present with more medical conditions. Several nonsurgical and surgical techniques have been employed to treat fractures of the atrophic (edentulous) mandible, including bone grafts, titanium mesh, gunning splint, transoral open reduction and internal fixation (ORIF) with miniplates, and ORIF with a load-bearing reconstruction plate using an extraoral approach.3,5–10 A conservative treatment can be considered for patients who are medically too compromised for general anesthesia, but only if spontaneous healing is expected. Complications such as nerve damage, infection, dehiscence, and nonunion may occur.2,11,12 If the height of the mandible is less than 10 mm, complications are more likely to occur.12,13

A Cochrane review failed to ascertain a specific treatment option and argued this choice should be based on the patient’s characteristics and clinician’s experience.14 The aim of this study is to analyze the outcome of fracture treatment of the atrophic edentulous mandible in our center.

Methods
A retrospective observational study was performed. From December 2010 to February 2016, all patients with fractures of the severely atrophic edentulous mandible in the Erasmus University Medical Center, Rotterdam, The Netherlands, were included. We defined the mandible as severely atrophic if the height of the symphysis of the mandible was 15 mm or less. All files were retrospectively studied. Patients with osteoradionecrosis of the mandible were excluded.

Results
Twelve patients (female, n = 8) with single (n = 6) or multiple fracture(s) (n = 6) of the atrophic edentulous mandible...
were identified. The mean age was 76 years (range: 58–94 years) (Table 1).

The mean height of the mandible was 10.1 mm as measured in the symphysis (range: 6.4–15 mm). All fractures occurred in the body of the mandible. The mean follow-up was 11 months (range: 1–41 months).

In seven cases, consolidation was successful following ORIF using a load-bearing reconstruction plate and locking screws via an extraoral approach (Figs. 1 and 2, Table 2). No bone grafts were used. The mean time registered between the traumatic event and fracture reduction was 6 days (range: 1–12 days). Fractures occurred in six cases following trauma and in one case following explantation of dental implants. In four cases, a bilateral fracture of the mandible occurred and in three cases a unilateral fracture occurred. In two cases, short dental implants were placed 4 to 7 months following fracture repair (height symphysis > 10 mm) (Fig. 3). Satisfactory dental rehabilitation was accomplished in five cases. In two cases, follow-up of the fracture and dental rehabilitation was organized in another hospital and the outcome is therefore unknown to the investigators.

Four months following removal of an implant 32, a fracture occurred after rehabilitation with an overdenture on the remaining fixtures 34, 42, and 44 (patient 8, Table 2). The patient was treated with a gnashing splint due to a medical history of stomach carcinoma and mitral valve insufficiency. Nonunion of the fracture occurred. The three remaining implants were removed gradually over time (8 months). After 13 months, ORIF using a load-bearing reconstruction plate and locking screws from an extraoral approach was initiated. Dental rehabilitation occurred 7 months later, with implants (6 mm) 33 and 43. Unfortunately, the osseointegration of implant 43 failed three times, and implant 33 failed in the end as well (12 months after placement). Conventional dentures without dental implants were advised and implemented. A hypoesthesia of the mental nerve persisted.

One patient had used bisphosphonates (risedronate) for 4 years (patient 9, Table 2). Following trauma, bilateral fractures of the mandible occurred (symphyseal height: 14.5 mm). An observational treatment was performed; however, nonunion of the fracture on the left side occurred. After 3 months, ORIF, using a load-bearing reconstruction plate with locking screws via an extraoral approach, was performed. Four implants 33, 31, 41, and 43 remained in situ and an overdenture bar was placed after 6 months. Good dental rehabilitation was accomplished. A hypoesthesia of the mental nerve on the left side persisted.

Following explantation of an implant 33, a fracture of the mandible occurred (patient 10, Table 2). The symphyseal height was 11.6 mm and an implant 43 was situated. The initial treatment consisted of ORIF using two miniplates which was performed in another hospital. Malunion of the fracture occurred. After 18 months, the patient was referred to our center. ORIF, using a load-bearing reconstruction plate with locking screws from an extraoral approach, was performed. An implant 33 will be placed to accomplish good dental rehabilitation.

Following trauma, a fracture on the left side of the mandible occurred (symphyseal height: 11.3 mm) (patient 11, Table 2). Initial treatment consisted of ORIF using two miniplates which was performed in another hospital. Malunion of the fracture occurred. After 6 weeks, the patient was referred to our center. ORIF using a load-bearing reconstruction plate with locking screws from an extraoral approach was performed. Dental rehabilitation was accomplished without implants.

Multiple fractures of the severely atrophic edentulous mandible (symphyseal height: 7.4 mm) occurred following trauma (patient 12, Table 2). The initial treatment was ORIF using five miniplates via an intraoral approach. Due to unsuccessful healing at the fracture site, a load-bearing reconstruction plate with locking screws from an extraoral approach was performed and the consolidation was uneventful. The final dental rehabilitation is unknown to the investigators as the follow-up was performed elsewhere.

Complications of ORIF using a reconstruction plate included damage of the mental nerve (n = 4, patients 1, 7, 8, and 9). In one patient, osseointegration of implants failed (patient 8). No damage of the facial nerve was observed.

Table 1 Patient characteristics

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>4</td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
</tr>
<tr>
<td>Mean age (y)</td>
<td>76.5 (58–94)</td>
</tr>
</tbody>
</table>

Fig. 1 Orthopantomogram of patient 2. Fracture of region 43 after explantation.

Fig. 2 Orthopantomogram of patient 2. Reconstruction plate situated on the mandible.
## Table 2 Fracture characteristics

<table>
<thead>
<tr>
<th>Patient</th>
<th>Cause of fracture</th>
<th>Height symphysis (mm)</th>
<th>Fracture site (region)</th>
<th>Initial treatment</th>
<th>Final treatment</th>
<th>Dental rehabilitation with implants</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Trauma</td>
<td>10.3</td>
<td>33 and 43</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>Yes. Postoperatively 2 implants were placed</td>
<td>Hypoesthesia mental nerve</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Explantation</td>
<td>10.5</td>
<td>41</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>Yes. Postoperatively 3 implants and an overdenture bar were placed</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Trauma</td>
<td>6.9</td>
<td>33 and 43</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>Unknown (follow-up in another hospital)</td>
<td>Unknown (follow-up in another hospital)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Trauma</td>
<td>14.0</td>
<td>44</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>No</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Trauma</td>
<td>6.6</td>
<td>36 and 41</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>Unknown (follow-up in another hospital)</td>
<td>Unknown (follow-up in another hospital)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Trauma</td>
<td>13.5</td>
<td>33</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>Three implants remained in situ</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Trauma</td>
<td>8.0</td>
<td>35 and 45</td>
<td>ORIF using a load-bearing reconstruction plate</td>
<td>No</td>
<td>Hypoesthesia mental nerve (left side)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Placing an overdenture bar</td>
<td>6.4</td>
<td>32</td>
<td>Gunning splint</td>
<td>ORIF using load-bearing reconstruction plate</td>
<td>Three times implants were placed. Unfortunately, the implants needed to be removed</td>
<td>Hypoesthesia mental nerve Failure of osseointegration</td>
</tr>
<tr>
<td>9</td>
<td>Trauma</td>
<td>14.5</td>
<td>36 and 46</td>
<td>Observational policy because of using risedronate</td>
<td>ORIF using load-bearing reconstruction plate</td>
<td>Four implants were preserved. An overdenture bar was placed</td>
<td>Hypoesthesia mental nerve (left side)</td>
</tr>
<tr>
<td>10</td>
<td>Explantation implant in region 33</td>
<td>11.6</td>
<td>32</td>
<td>ORIF using 2 miniplates</td>
<td>ORIF using load-bearing reconstruction plate</td>
<td>An implant will be placed in region 33</td>
<td>None</td>
</tr>
<tr>
<td>11</td>
<td>Trauma</td>
<td>11.3</td>
<td>35</td>
<td>ORIF using 2 miniplates</td>
<td>ORIF using load-bearing reconstruction plate</td>
<td>Unknown (follow-up in another hospital)</td>
<td>None</td>
</tr>
<tr>
<td>12</td>
<td>Trauma</td>
<td>7.4</td>
<td>35, 43, and 46</td>
<td>ORIF using 5 miniplates</td>
<td>ORIF using load-bearing reconstruction plate</td>
<td>Unknown (follow-up in another hospital)</td>
<td>Unknown (follow-up in another hospital)</td>
</tr>
</tbody>
</table>

Abbreviation: ORIF, open reduction and internal fixation.
**Discussion**

Our case series and review of the literature show that using a load-bearing reconstruction plate with locking screws from an extraoral approach leads to a good consolidation of a fractured severely atrophic mandible.\(^2,6,7,10\) Complications following ORIF using a reconstruction plate occurred in four patients (permanent hypoaesthesia mental nerve). No nonunion or malunion was seen in our case series. However, malunion following ORIF using a load-bearing reconstruction plate from an extraoral approach has been reported in the literature. In this case, the initial treatment consisted of the application of miniplates that led to malunion.\(^15\) Disadvantages of using the load-bearing reconstruction plates are the requirement for general anesthesia and an extraoral scar. An intraoral approach with exposure of the mandible from angle to angle may further compromise the vascularization of the bone, which is already weak. This approach is therefore not advisable. Via an extraoral approach, more visibility is achieved and the bone fragments can be repositioned and stabilized with temporary miniplates on the caudal side of the mandible facilitating the application of the reconstruction plate on the buccal site. These miniplates can be removed when the reconstruction plate is positioned. With regard to deciding which position is best for the load-bearing reconstruction plate, it has been found that there are no mechanical differences when placing the plate on the buccal or inferior rim of the mandible.\(^16\)

Following observation and using a gunning splint, malunion or nonunion are the main complications which were observed in our clinic and when studying the literature.\(^5,17\) Using miniplates for reconstruction of fractures of the severely atrophic mandible seems to be an attractive treatment option as it can be performed under local anesthesia and an extraoral scar can be avoided. However, nonunion may occur.\(^5,6,15\) Poor bone healing after a fracture of the atrophic edentulous mandible might be due to the bony reduction of the mandible and the relative increase of dense cortical bone leads to less vascularity and blood flow.\(^7,18\)

Following loss of teeth, a continuous reduction of the mandible height over the years can be seen.\(^19,20\) Several studies have been performed with the aim to investigate how the mandible changes when becoming edentulous. It was found that the mandibular height decreased when edentulous patients grew older. The mandibular resorption rate was greatest in the earlier stages of edentulism and slowed with the longevity of edentulism.\(^21,22\) Being an elderly female or having asthma are found to be risk factors for mandibular atrophy.\(^23\) It has been reported that in edentulous jaws, implant-supported prostheses could prevent further resorption of the mandibular bone.\(^24\)

In our case series, more fractures occurred in female patients and following trauma. Osteoporosis is a frequently seen problem in the older patient, with a predominance in females. In 2015 in The Netherlands, 43 of 1,000 females and 7.5 of 1,000 males were suffering from osteoporosis. The prevalence increases with age.\(^25\) Following minor trauma, fractures may occur in patients with osteoporosis, although most fractures occur in the spine, hip, wrist, humerus, and pelvis.\(^26\) Patients with osteoporosis have less mandibular bone mass and density and may be more often edentulous compared with patients who do not have osteoporosis.\(^27\) These changes in quality of bone as seen in osteoporosis are likely to contribute to the incidence of fractures of the atrophic edentulous mandible.\(^27,28\)

In one patient with long term use of bisphosphonates for osteoporosis, a bilateral mandibular fracture occurred following trauma. Bisphosphonate or medication-related osteonecrosis of the jaw (MRONJ) is a well-known and described disease that seriously impairs the bone quality. Treatment of fractures in MRONJ-affected mandibles is difficult because outcome is unpredictable and treatment guidelines are not yet established.\(^29\) In the literature, it is advised that the initial approach should be as conservative as possible.\(^30\) In the case we have presented, the initial chosen policy (observation) led to nonunion (patient 9). In the literature, two cases were described in which initial treatment using miniplates did not lead to good rehabilitation.\(^31,32\) The more aggressive approach (ORIF using a load-bearing reconstruction plate) led to the healing of the fracture in these cases.\(^31,32\)

It appears that mandibular implant-supported overdentures lead to less bone loss and possibly induce bone growth.\(^24\) Furthermore, function, pain, and psychosocial problems related to their dentures may improve with implants.\(^1,33\) To achieve optimal dental rehabilitation, implants should be considered even in severely atrophic edentulous mandibles. Although implant placement in these fragile mandibles are rarely complicated by a fracture, the burden for the individual patient is still considerably high. It has been described that in mandibles with less than 10 mm of height, the occurrence of fractures in conjunction with implant placement is low.\(^1,3\) Following implant placement or removal, atrophic edentulous mandible (symphyseal height: < 15 mm) fractures occurred in four cases (in a total of 916 patients; 0.44%).\(^3\) Another study reported that 0.05% of edentulous mandibles fractured in conjunction with implant treatment, and these fractures only occurred when the jaw was < 10 mm in height measured in the symphysis.\(^4\) More cases have been described in which a fracture of the (atrophic edentulous) mandible occurred following implant placement or removal.\(^34–38\) In our case series, fractures of the severely atrophic edentulous mandible were
related to implants in 25% of the cases (explantation of dental implants \(n = 2\) and placing an overdenture bar \(n = 1\)). It is advisable to inform the patient preoperatively about the low risk of fracture when considering implants in the severely atrophic (edentulous) mandible.

Conclusion

Our case series and review of the literature show that in case of fractures of the atrophic (edentulous) mandible, the currently described treatments are not uniform. However, more complications with considerably higher burden for the patients are seen if ORIF using load-bearing reconstruction plate is not directly performed. In case of a severely atrophic mandibular fracture, we advise ORIF using load-bearing reconstruction plate with locking screws.\(^{39}\) In selected cases, secondary oral rehabilitation with short dental implants and implant-supported prosthesis is feasible.

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None.

Meetings at Which the Paper has been Presented

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