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ORIGINAL ARTICLE

Bone resorption and complications in alveolar distraction osteogenesis

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Abstract Distraction osteogenesis presents an alternative procedure for augmentation of atrophic alveolar bone prior to inserting dental implants. The aim of this retrospective study was to evaluate complications of this method with specific focus on bone resorption during the consolidation period and the follow-up period after dental implant insertion into distracted bone. Thirty partially edentulous patients underwent a total of 36 vertical alveolar distractions with an extraosseous distraction system. Eleven devices were placed in the maxilla and 25 in the mandible. Eighty-two dental implants were inserted after a mean consolidation period of 4.5 months. Treatment results were evaluated by means of panoramic radiographs for distraction follow-up and periapical radiographs for implant follow-up. The mean length of the transport segment was 19 mm. The average alveolar height achieved was 6.4 mm with a mean resorption of 1.8 mm (21.1%) at the time of dental implant insertion. Main problems comprised oral displacement of the transport segment (n=15) and inadequate soft tissue extension (n=13). Eighty-two dental implants were inserted with an overall survival rate of 95.1% after 45.8 months. For periimplant marginal bone, an average resorption of 3.5 mm was recorded 50.4 months after implant insertion. Although alveolar distraction osteogenesis seems to be an effective tool to treat vertical defects of the alveolar ridge, it is not an uncomplicated procedure. A combination with vestibular augmentation of autogenous bone grafts should be considered. Overcorrection of 20% may compensate bone relapse during the consolidation period of the distracted alveolar bone. Further bone resorption after dental implantation is common.

Keywords Alveolar distraction osteogenesis · Complications · Bone resorption

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Introduction

Alveolar distraction osteogenesis (ADO) has evolved as a promising procedure for alveolar ridge augmentation prior to implant placement. Although there is a spectrum of alternative reconstructive and regenerative methods like the use of autogenous bone grafting [1–3], allografts [4], xenogenic [5–7], or alloplastic materials [8] with or without guided bone regeneration (GBR), ADO offers a couple of unique advantages since it avoids donor site morbidity and provides predictable gain of hard and soft tissues. Further advantages are low infection rate, decreased bone resorption, and a short bone consolidation period prior to implantation [9, 10].

On the other hand, there is a variety of complications that has been reported in the context of ADO. Specifically, the problem of oral vector tip of the transport segment [11–14], semilunar excavation of the augmented buccal bone [14–16], fracture of basal bone [13, 15], and various device failures [11, 15] have been recognized. Moreover, due to the widespread use of distractors according to variable protocols, there is no consensus on several therapeutic aspects like the duration of the latency period or the amount of overcorrection required.

While bone loss in patients with free autogenous onlay grafts amounts up to 42% [17], data for mean bone resorption during the consolidation period of ADO are highly variable and range from "insignificant" [18] to about 30% [16]. Thus, the purpose of this retrospective study was to evaluate intra- and postoperative complications of alveolar distraction osteogenesis in a cohort of partially edentulous patients, with specific focus on bone resorption during the consolidation period and the follow-up period after implant insertion into distracted bone.

Materials and methods

Patients

From July 1998 until May 2003, 30 partially edentulous patients (mean age 38.6 years) consecutively underwent alveolar distraction osteogenesis with a total number of 36 extraosseous distractors (Track® Distractor 1.0 or 1.5 mm, Martin, Tuttlingen, Germany). Twenty-one distractions were carried out in females, 15 in males. Eleven devices were inserted in the maxilla and 25 in the mandible. The alveolar defects were either caused by periodontal disease (21) or resulted from traumatic tooth loss (12). Indications for distraction osteogenesis were single-tooth gaps in six patients, free-end gaps in 13 patients, and interdental spaces in 17 patients. In 27 patients, 82 implants of different types (two Camlog®-Implants, Camlog Biotechnologies, Basel, Switzerland; seven Astra®-Implants, Astra Tech, Mölndal, Sweden; 73 ITI®-Implants Straumann, Basel, Switzerland) were inserted. Follow-up of the implants was performed for 16 (nine female, seven male) patients with 19 extraosseous distractors. Loss of implant was assessed as end point for implant survival.

Surgical procedure

The surgical treatment was performed in local anesthesia: The vestibular bone was exposed by a horizontal para-crestal incision, preserving the crestal and oral soft tissues for blood supply of the later bone segment. Lateral release incision allowed for buccal mucoperiosteal flap elevation providing access to the prospective osteotomy site (Fig. 1a). The outline of the osteotomy was marked by a fissure bur prior to adaptation of the distractor. The distraction vector was slightly directed to the vestibular aspect (Fig. 2). The osteotomy was performed using a reciprocating saw and the transport segment was finally mobilized with an osteotome. Care was taken to preserve the lingual and palatal soft tissue pedicle. The lateral vertical bone cuts were placed in an angulated manner to achieve a trapezoid-shaped bone segment. This osteotomy design was chosen to prevent oral displacement of the mobilized segments. Once the osteotomy was completed, the distractor was fixed to the transport segment and the basal bone with monocortical titanium microscrews. In order to identify obstacles in the distraction path, the distractor was activated immediately (Fig. 1b). The mucoperiosteal flap was repositioned,

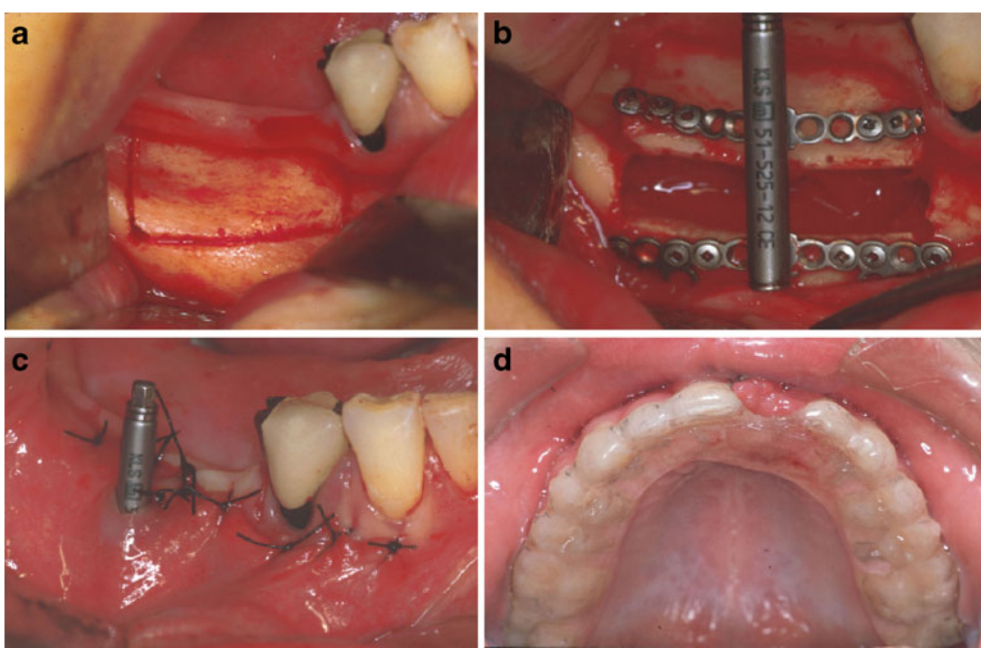

Fig. 1 **a** Elevated mucoperiosteal flap with marked osteotomy lines after horizontal incision in height of the alveolar crest with vertical releasing incisions. **b** Activation test of fixed distractor (1.5 mm device). **c** Closed mucoperiosteal flap with exposed rod for activation. **d** Miniplast splint with lingual support of the transport segment

Fig. 2 The model shows the adapted device with a vestibular vector tip bending

leaving the coronal part of the distractor exposed to allow activation (Fig. 1c). The patients received antibiotics (Clindamycin 3×600 mg p.o.) for a maximum of 10 days. Standard radiographs (orthopantomogram) were performed at the first postoperative day. To ensure mechanical control of the distraction vector, the distractors were splinted via appropriate miniplast devices (Fig. 1d).

After a mean latency period of 8.1 days (range 6–13 days), the distractors were activated with a transport rate of 0.9 mm/day (three activations of 0.3 mm for track distractor 1.0 mm) or 1 mm/day (two activations of 0.5 mm for track distractor 1.5 mm). Elongation of the latency period up to 13 days was due to organizational obstacles on the part of the patients. The mean active distraction time accounted for 12.8 days (range 7–26 days). Extension of the distraction time became necessary if the patient reported increasing tension and pain going along with hindered rotation of the distractor rod. The distractors were removed at an average of 2.5 months (77.4 days) after the final activation. For reasons as deficient ossification of the callus (Fig. 3), soft tissue dehiscence, or inadequate fixed gingiva, insertion of dental implants was prolonged to an average of 2 months, resulting in an overall mean consolidation period of 4.5 months (135.9 days).

Radiographic evaluation

Treatment results of the distraction osteogenesis were evaluated by means of panoramic radiographs. The distance between the upper edge of the lower plate and the alveolar crest was measured after distractor insertion and at the end of the distraction period. The difference of the two heights revealed the vertical distracted bone gain. The difference between the vertical extension of the two distractor plates and the distracted bone gain showed bone relapse. Prior to distractor removal, the distance between sinus floor or adjacent dental roots and crestal bone was measured for the upper jaw. For the lower jaw, the distance between the inferior margin of the mandible and the alveolar crest was assessed, so that alterations in bone height could also be observed after distractor removal. Bone height immediately after distraction minus final bone height after implantation (end of consolidation period) represented definite bone relapse. Radiographic dimensional distortion was corrected by the relation of the known true dimension of the distractor rod to the measured rod dimension in the radiograph.

The marginal bone of the implants was evaluated by single-tooth periapical radiographs. Each radiograph was calibrated using the known width of the coronal cylinders of the implants. The lower corner of the cylinders was used as reference point and its relation to the marginal bone level was measured. Moreover, the distance from the initial bone level to the bone level at follow-up examinations was calculated in order to reflect the true bone resorption

Statistics

Study data were retrospectively obtained from follow-up investigations and patient charts. Statistical analysis mainly was of descriptive manner. Bone height and bone resorption after distraction osteogenesis and implant insertion were expressed as means with range values. Fisher's exact probability test ($p<0.05$) was used for analysis of categorical dichotomized variables and relationships. Implant survival was assessed as percentage of implants "in situ" at the end of follow-up in relation to implants primarily inserted.

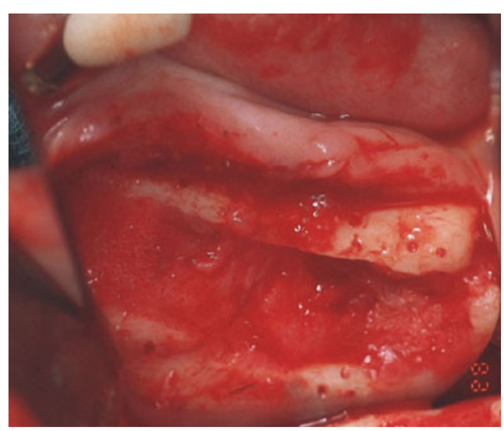

Fig. 3 Deficient ossification of the callus after distractor removal

Results

Bone gain

The mean length of the distracted segment was 19 mm (range 6–36 mm). The average vertical augmentation immediately after distraction was 8.1 mm (range 5–14 mm). In the maxilla, bone gain measured a mean of 7.9 mm (range 7–10 mm), in the mandible 8.2 mm (range 5–14 mm). The mean vertical bone height after implantation was 6.4 mm (range 4–12 mm) with 6.3 mm (range 5–8 mm) in the maxilla and 6.4 mm (range 4–12 mm) in the mandible (Table 1). Average bone relapse after the consolidation period measured 1.6 mm (19.8%, range 0–3 mm) in the maxilla and 1.9 mm (21.6%, range 0–4 mm) in the mandible with a total mean relapse of 1.8 mm (21.1%). With view to the defect type, mean vertical bone gain was higher for interdental spaces (6.5 mm) than for free-end gaps (6.1 mm). However, distracted interdental bone also showed a higher mean bone relapse of 2.1 mm (23.6%) in comparison to distracted free-end bone (1.2 mm, 16.1%). Referring to the distracted segment length, bone gain and bone resorption were similar for smaller (length <20 mm; bone gain 6.3 mm; resorption 1.8 mm, 21.4%) and longer (length >20 mm; bone gain 6.4 mm; resorption 1.8 mm, 20.7%) segments (Table 1). For patients with a latency period of 10 days or more ($n=5$), a lower mean vertical bone gain of 5.4 mm was recorded going along with a lower bone resorption of 1.2 mm (18.0%). Patients with a prolonged active distraction time of more than 20 days ($n=7$) presented superior bone gain (6.6 mm) but also a higher mean resorption of 2.2 mm (26.0%).

The cases who required extended (>5 months) consolidation periods ($n=8$) were not related to those with extended (≥10 days) latency periods ($p=1.0$). Patients with a consolidation period of more than 5 months ($n=8$) presented a higher mean vertical bone gain of 6.7 mm accompanied by a higher bone relapse of 2.3 mm (25.8%) immediately after dental implant insertion.

Complications

A total of 33 complications postoperative and during distraction and consolidation period were observed. In 15 cases (four maxilla, 11 mandible, 41.7%), oral displacement of the transport segment occurred, despite the device bending and the supporting miniplast splint. The performed osteoplastic measurements included corrective osteotomy of the distracted bone segment or vestibular augmentation with minor autogenous bone grafts. Oral displacement was independent of jaw location, defect type, and active distraction time (Table 1). Longer (>20 mm, $n=18$) transport segments presented a higher rate (55.6%) of oral vector tips with necessity of osteotomies in comparison to shorter (<20 mm, $n=18$) segments (27.8%). Elongations of the latency period (≥10 days) and the consolidation period

Table 1 Distraction characteristics and outcome

Variable	Mean bone gain (mm)[b]	Mean bone relapse (mm)	Missing soft tissue extension	Oral vector tip	Total
Jaw					
Maxilla	6.3	1.6 (19.8%)	3 (27.3%)	5 (45.5%)	11
Mandible	6.4	1.9 (21.6%)	10 (40.0%)	10 (40.0%)	25
Defect type					
Interdental spaces	6.5	2.1 (23.6%)	8 (33.3%)	10 (41.7%)	23[c]
Free-end gap	6.1	1.2 (16.1%)	5 (41.7%)	5 (41.7%)	13
Segment length					
≤20 mm	6.3	1.8 (21.4%)	5 (27.8%)	5 (27.8%)	18
>20 mm	6.4	1.8 (20.7%)	8 (44.4%)	10 (55.6%)	18
Latency period					
6–9 days	6.5	1.9 (21.5%)	13 (41.9%)	14 (45.2%)	31
10–13 days	5.4	1.2 (18.0%)	0	1 (20.0%)	5
Distraction time					
7–20 days	6.3	1.7 (19.9%)	10 (34.5%)	12 (41.4%)	29
>20 days	6.6	2.2 (26.0%)	3 (42.9%)	3 (42.9%)	7
Consolidation period[a]					
<5 months	6.3	1.6 (19.7%)	10 (35.7%)	13 (46.4%)	28
>5 months	6.7	2.3 (25.8%)	3 (37.5%)	2 (25.0%)	8
Total	6.4	1.8 (21.1%)	13 (36.1%)	15 (41.7%)	36

[a] Time from final activation to implant insertion

[b] After implant insertion

[c] Interdental spaces ($n=17$) and single-tooth gaps ($n=6$)

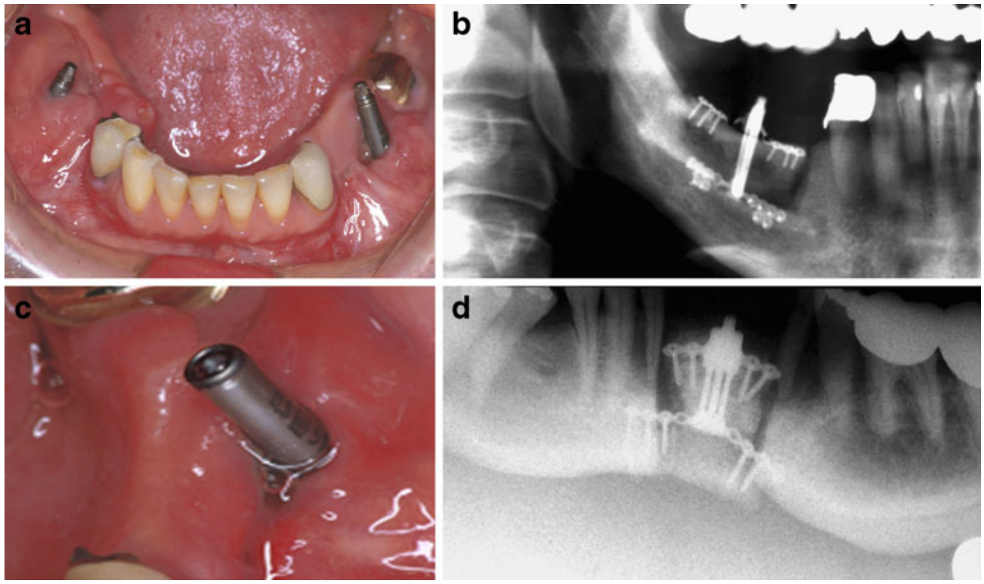

Fig. 4 Complications during and postdistraction osteogenesis. **a** Plain vestibular sulcus and scarred fibrous mucosa after distraction. Missing fixed gingiva. **b** Device breakage. **c** Rod failure. **d** Mandibular fracture of the basal bone during consolidation period

(>5 months) went along with a lower occurrence (20% and 25%, respectively) of oral displacement of the transport segment.

In 13 cases (36.1%), extension of the fixed gingiva was missing resulting in inadequate morphology of the buccal vestibule (Fig. 4a). A vestibuloplasty with a free mucosal graft from the palate was necessary in these patients. Missing soft tissue extension occurred more often with distraction of mandibular bone (40%), in cases of free-end gaps (41.7%), with longer (>20 mm) transport segments (44.4%) as well as with elongations (≥20 days) of the active distraction time (42.9%). Soft tissue extension was independent of the consolidation period. In all five cases with a prolonged latency period (≥10 days), soft tissue extension of the fixed gingival was proper (Table 1).

In two patients, device failure—plate (Fig. 4b) and rod (Fig. 4c) fracture—required a new distractor insertion. Two soft tissue dehiscences occurred without infection. In one case, fracture of the mandible appeared (Fig. 4d) and was treated by an adjusted cap splint fixed to the mandibular arch with circumferential wiring for 44 days without further complications or occlusal disturbance (Fig. 5). No infection was observed postoperative or during the distraction period in any patient.

Dental implantation

In 27 patients, a total of 82 implants (median 2.4 per patient) were inserted. Four implants of three patients failed. One immediate loss and three explantations due to periimplantitis were recorded. Implant survival rate was 95.1% after an average of 45.8 months (range 0.72–67.9 months).

Follow-up of the implants was performed on 16 patients (nine female, seven male) in a mean interval of 50.4 months after implant insertion. A median periimplant marginal bone loss of 3.5 mm (range 0.5–9 mm) was observed resulting in a yearly marginal bone loss of 0.87 mm.

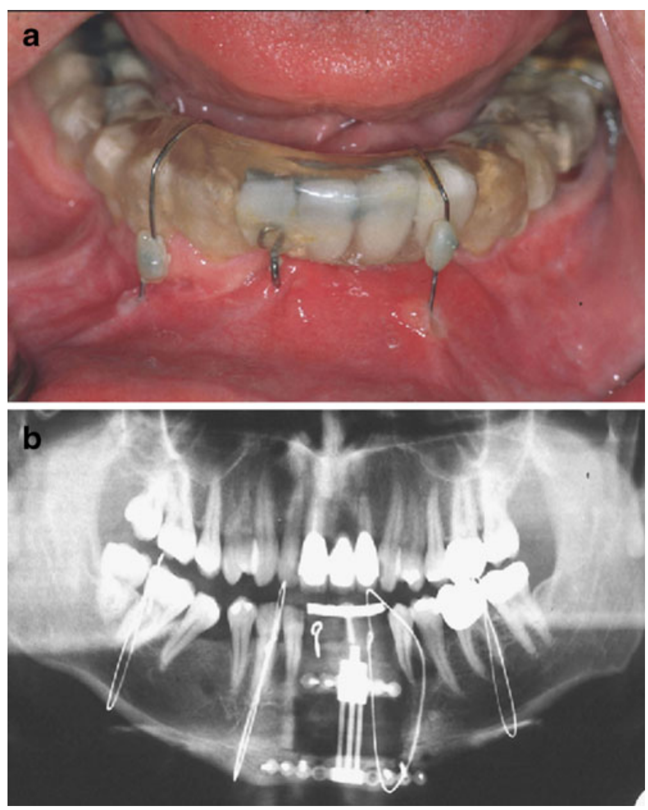

Fig. 5 Treatment of the basal bone fracture. **a** Adjusted cap splint. **b** Fixation with circumferential wirings

Discussion

Successful reconstruction of vertical alveolar bone defects in partially or totally edentulous patients is reported for augmentation of autogenous bone grafts (ABG) as well as for distraction osteogenesis (ADO) [19–21]. For ABG, bone resorption of 25% to 42% is described [2, 17], and average vertical bone gain seems to be limited to 5 mm in partially edentulous patients [2, 22]. For ADO, mean vertical bone gain up to 12 mm [23, 24] is reported but data for bone relapse are varying. Table 2 shows mean bone gain and average bone relapse in recent studies. McAllister [18] could find no significant bone resorption during consolidation period in an investigation of ten intra-osseously placed distractors. Chiapasco et al. [13] obtained in a multicenter study a minimal median resorption of 0.3 mm (3%) after a consolidation period of 2–3 months using extraosseous rigid devices. By means of the same distractor device as this group, the results of the present study, however, showed a mean bone gain of 6.4 mm and an average bone relapse of 1.8 mm (21.1%) after a consolidation period of 4.5 months, which is in accordance with the 20% resorption rate of Wolvius et al. [14], who also used a rigid extraosseous device. Bone resorption seems not only to depend on the use of a rigid or a semirigid distractor device, as Saulacic et al. [25] supposed, describing a bone relapse of 26–29% with an intraosseous semirigid distractor in their investigation. The length of the distracted segments may also influence bone resorption. Small segments, e.g. after single tooth defects, are reported to be associated with higher bone resorption and complication rates due to dense screw fixation and worse vascularization [14]. In the own analysis, bone resorption was independent of the segment length. However, distraction of interdental space defects including single-tooth defects presented higher bone relapse rates than free-end gap defects. Also, bone resorption seems to be higher in distraction of mandibular bone in comparison to bone of the maxilla. While elongations in the latency period of 10 days and more did not result in increased bone relapse in our study, a prolonged active distraction time of more than 20 days as well as extensive consolidation periods may bring about higher bone resorption. In the present study, part of the bone relapse had to be attributed to smoothing the alveolar crest prior to insertion of the implants. So different surgical procedures as well as the moment of bone height measurement (prior or post implantation) have to be considered in evaluating bone relapse. Nevertheless, an overcorrection of 15–20% as proposed in current investigations [14, 25, 26] can be confirmed.

Beside known advantages of ADO like decreased morbidity, minor bone resorption, and extension of soft tissues [9, 11], various complications related to surgical techniques, devices, and resulting bone quality are reported (Table 3). A total of 33 complications were observed in the present investigation. The most common problem (15 cases, 41.7%) was oral displacement of the transport segment, as a result of the thick and rigid mucosa of the maxilla and the pulling lingual muscles such as the mylohyoid [13, 18, 27]. This oral vector tip seems to occur more likely when segments longer than 20 mm are distracted, while elongations in the latency period, active distraction time, or consolidation period seem not be associated with increased probability of oral displacement of the transport segment.

Neither angular overcorrection of the device in the vestibular direction nor the use of a vector supporting splint could prevent this oral displacement, so that corrective osteotomy or augmentation of autogenous bone grafts was necessary. Additionally to the oral tipping, buccal bone defects and semilunar excavations of the transport segment are often described [11, 14, 16, 28], increasing the vestibular bone deficit. In these cases, a combination of vertical distraction osteogenesis with autogenous bone grafts should be performed showing the best aesthetic results in reconstructing alveolar bone

Table 2 Recent studies referring to bone relapse in alveolar distraction osteogenesis

Author	Distractor system	Intraosseous/ extraosseous	Cases	Consolidation period (weeks)	Mean bone gain (mm)	Mean bone relapse (mm)
McAllister et al. [18]	OGD Distractor (Ace)	Intraosseous	10 (mand)	12	7	Not significant
Jensen et al. [11]	3i Implant-Distractor n=10, Osteomed Quick-fix n=20	Intraosseous	30 (28 max, 2 mand)	8–10	6.5	1.6 (25%)
Chiapasco et al. [13]	Track Distractor (Martin)	Extraosseous	37 (9 max, 28 mand)	8–12	9.9	0.3 (3%)
Polo et al. [26]	Track Distractor (Martin)	Extraosseous	14 (mand)	8–12	5.1	0.9 (17.6%)
Saulacic et al. [25]	Lead Distractor (Leibinger)	Intraosseous	17 (2 max, 15 mand)	12	6.2	1.6 (26%)–1.8 (29%)
Wolvius et al. [14]	Track Distractor (Martin)	Extraosseous	20 (12 max, 8 mand)	11–16	4.6–5.3	1.2 (20%)–1.5 (17%)
Own study	Track Distractor (Martin)	Extraosseous	36 (11 max, 25 mand)	18	6.4	1.8 (21.1%)

mand mandible, *max* maxilla

Table 3 Recent publications referring to complications in alveolar distraction osteogenesis

Author	Distractor system	Cases	Oral vector tip	Other complications	Treatment
Klug et al. [28]	Track Distractor (Martin)	13 (mand)	–	Vestibular bone deficit (6), dehiscence (2), device failure (1), migration of soft tissue in distraction gap (6)	4 GBR (titanium membranes)
McAllister et al. [18]	OGD Distractor (Ace)	10 (mand)	–	Vestibular bone deficit (2)	2 MBG (anorganic bovine)
Rachmiel et al. [20]	Lead Distractor (Leibinger)	15 (6 max, 9 mand)	–	Paresthesia (1), device failure (1)	–
Jensen et al. [11]	3i Implant-Distractor $n=10$, Osteomed Quick=fix $n=20$	30 (28 max, 2 mand)	11 (palatal)	Poor bone quality (11), inadequate soft tissue extension (12), device failure (6)	18 MBG, 12 vestibuloplasties
Zaffe et al. [23]	Track Distractor (Martin)	10 (mand)	1	Inadequate soft tissue extension (3)	1 corrective osteotomy, 3 vestibuloplasties
Chiapasco et al. [13]	Track Distractor (Martin)	37 (9 max, 28 mand)	5 (3 lingual, 2 palatal)	Vestibular bone deficit (1), basal bone fracture (1), incomplete distraction (1)	1 MBG
Enislidis et al. [15]	Lead Distractor (Leibinger) $n=14$; Track Distractor (Martin) $n=31$	45 (mand)	–	Vestibular bone deficit (11), basal bone fracture (3), fracture of transport segment (1), device failure (4), paresthesia (6), soft tissue dehiscence (37, 8%), infection (3)	11 MBG, 3 GBR
Iizuka et al. [29]	V2 Alveolar Distractor (Medartis)	8 (3 max, 5 mand)	2 (lingual)	Vestibular bone deficit (2)	2 MBG, 2 corrective osteotomies
Polo et al. [26]	Track Distractor (Martin)	14 (mand)	1 (lingual)	Infection (3), paresthesia (2), resistance to rotating (2)	–
Marchetti et al. [32]	Track Distractor (Martin)	10 (2 max, 8 mand)	1 (lingual)	Vestibular bone deficit (1), inadequate soft tissue extension (1)	1MBG, 1 vestibuloplasty
Mazzonetto et al. [27]	Implant system (Conexão)	55 (24 max, 31 mand)	3	Vestibular bone deficit (3), fracture of transport segment (1), device failure (1), lack of device activation (3), epithelial invagination (1), nonunion (1), infection (8), paresthesia (6), hyperplasia (3), dehiscence (3), screw fracture (2)	21 MBG, 80.9% in anterior maxillary region
Saulacic et al. [16]	Lead Distractor (Leibinger) $n=21$; Modus Distractor (Medartis) $n=8$	29 (2 max, 27 mand)	5 (lingual)	Vestibular bone deficit (17), fracture of transport segment (3), difficult lingual osteotomy (7), rod interference (3), paresthesia (6), dehiscence (4)	17 MBG, 1 corrective osteotomy, 1 GBR
Uckan et al. [24]	Lead Distractor (Leibinger) $n=13$, Modus (Medartis) $n=10$	23 (13 max, 10 mand)	7 (3 lingual, 4 palatal)	Fracture of transport segment (1), dehiscence (1), rod interference (3)	–
Wolvius et al. [14]	Track Distractor (Martin)	20 (12 max, 8 mand)	10 (4 lingual, 6 palatal)	Vestibular bone deficit (10), fracture of transport segment (1)	10 MBG, 5 major (iliac crest) grafting
Own study	Track Distractor (Martin)	36 (11 max, 25 mand)	15 (11 lingual, 4 palatal)	Inadequate soft tissue extension (13), device failure (2), dehiscence (2), basal bone fracture (1)	12 MBG, 3 corrective osteotomies, 13 vestibuloplasties

GBR guided bone regeneration, *mand* mandible, *max* maxilla, *MBG* minor bone graft (mainly autogenous) defects. Klug et al. [28] proposed the application of titanium membranes for GBR for producing a physiological shaped alveolar ridge. An alternative technique may be the use of bidirectional extraosseous devices, which allow a labial orientation of the transport vector [29, 30]. Further investigations with this device will be necessary. A recent publication described vector control of the malpositioned segment by using rubber traction toward a wire splint attached to the adjacent teeth [31].

Often-mentioned soft tissue complications are dehiscences [15, 16, 27] and failed lengthening of the fixed gingiva, resulting in a reduced vestibular sulcus [11, 23, 32]. Soft tissue dehiscences more frequently occur by the use of extraosseous devices [15, 27, 28], which demand a larger covering mucoperiosteal flap and enforce the tension caused by surrounding cheek and tongue muscles. Expansion of local fixed gingiva is stated as one of the main advantages of alveolar distraction osteogenesis [9, 10]. In the present study, however, 13 (36.1%) vestibuloplasties with free mucosal grafts from the palate were necessary, due to a reduced vestibular sulcus and to the presence of dense scarred mucosal fibrous tissue. According to our results, missing soft tissue extension may be more common with distraction of mandibular bone and increased length of the transport segment, while a prolonged latency period, active distraction time, or consolidation period did not result in higher rates of failed soft tissue lengthening. A possible reason for this mucosal extension failure might be the performed vestibular horizontal incision in height of the alveolar crest with two vertical releasing incisions during surgical procedures, which may have induced the described scars, inhibiting the formation of an adequate fixed gingiva. Therefore, a full thickness vestibular incision in the lower vestibule without lateral releasing incisions, as carried out by others [13–15], may prevent the described mucogingival complications and create aesthetic and stable periimplant soft tissue.

Device failure, mostly breakage, is described in various reports [11, 15, 27] and can result in insufficient bone gain. In the own study, both distractors were changed without further complications or bone loss.

Fractures of the basal bone or the transport segment have also been described before [11, 12, 15]. The own fracture occurred in a mandible with a residual vertical bone height after horizontal osteotomy of 5 mm. In accordance with Chiapasco et al. [13] who claimed a minimal residual bone height of 5 mm, treatment of extremely atrophic mandibles is limited and may require onlay bone grafts.

The survival rate of dental implants inserted in distracted bone—95.1% after 45.8 months in the own study—seems to be similar to implants placed in autogenic bone [33]. A mean marginal bone loss of 3.5 mm (after 50.4 months) was observed as the result of a combined horizontal and vertical bone resorption. This bone resorption of 0.87 mm per year is comparable to other studies describing even higher values of bone loss [34].

It can be summarized that alveolar distraction osteogenesis presents an effective technique to gain local and matured bone tissue prior to implant insertion with low morbidity, low infection rates, and minor resorption. However, complications like oral displacement of the transport vector and inadequate soft tissue extension after distraction may arise, especially with increased length of the transport segment. Additionally, bone fracture or device failure may occur. A combination with vestibular augmentation of autogenous bone grafts should be considered. Overcorrection of 20% may compensate bone relapse during the consolidation period of the distracted alveolar bone. High survival rates of dental implants can be achieved in distracted bone but further marginal bone resorption during follow-up is common.

Conflict of interest The authors declare that they have no conflict of interest.

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