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3D-based full-guided ridge expansion osteotomy – A case report about a new method with successive use of different surgical guides, transfer of splitting vector and simultaneous implant insertion

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ABSTRACT

For horizontal bone deficiency alveolar ridge osteotomy is considered an option for augmentation. Major advantages are the option for a one-stage approach and the absence of donor site morbidity. However, the conventional technique is associated with complications such as perforations and fractures of the cortical bone.

A case using a 3D based modified, full-guided alveolar ridge expansion is described to explain the technique step by step. Main features of modified technique: successive application of surgical guides for ridge osteotomy and expansion – implementation of virtually determined splitting vector, which allows guided bone splitting along a guide surface of template in an ideal direction - osteotomy as deep as implant length. The example shows that the 3D based modified alveolar ridge osteotomy is a suitable alternative to the conventional technique as it has several advantages such as fewer fractures and perforations of the cortical vestibular bone.

The individualized preoperative planning helps to minimize complications. However, long-term outcomes and a study, conducted on a study group, is needed to evaluate the benefits of our presented treatment protocol.

1. Introduction

A sufficient bone thickness is required for successful long-term results of endosseous implants (Nguyen et al., 2016). However, within the first six months after tooth loss, the width of the alveolar ridge decreases significantly (approximately 60%), especially at the expense of the buccal bone plate, thus creating a horizontal deficiency (Elnayef et al., 2015; Kolerman et al., 2014). Hence, proper implant insertion into the bony envelope is more difficult and may require alveolar ridge augmentation (Nguyen et al., 2016; Kolerman et al., 2014). A large variety of techniques has been described. They are based on autogenous bone grafts, guided bone regeneration and ridge expansion osteotomies (Kaneko et al., 2013). Although autogenous bone grafts, such as onlay block grafts or iliac crest grafts, still remain the gold standard for augmentation, these techniques are associated with a significantly higher morbidity rate due to the affection of the donor site and/or necessitate additional surgical interventions and longer treatment periods (Nguyen et al., 2016; Khoury et al., 2007). Guided bone regeneration (GBR) is also a frequently used method to obtain expansion of the alveolar ridge, however it is associated with an increased risk of infection, inflammation and wound healing disturbances (Kaneko et al., 2013; Aghaloo and Moy, 2007). Furthermore, the success of this technique depends on the materials used (resorbable/non-resorbable membranes) (Aghaloo and Moy, 2007). Another method to enlarge the horizontally deficient alveolar ridge is the alveolar ridge expansion osteotomy (syn. bone splitting) with subsequent spreading. It was introduced initially by Simion et al., in 1992 and

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numerous studies indicated the advantages of this technique enabling the option of simultaneous implant placement, avoiding donor site morbidity, and having shorter treatment periods (Jamil and Al-Adili, 2017; Simion et al., 1992). In a systematic review of Milinkovic et al., the alveolar crest-split technique has been found to have minimal technical complications and high implant survival rates (Milinkovic and Cordaro, 2014). Generally, this technique creates a greenstick fracture with lateral positioning of the buccal cortical plate of the atrophied alveolar ridge (Jha et al., 2017). According to the Cologne defect classification, bone splitting is suitable to compensate horizontal deficits of up to a maximum of 8 mm. Deficits of larger dimensions require further bone augmentation procedures (Nickenig et al., 2014). At least 1 mm of trabecular bone is necessary to maintain sufficient blood supply after bone spreading (Jha et al., 2017).

Furthermore, bone splitting is indicated for patients with combined horizontal-vertical defects when removable implant prosthesis compensates the vertical defect. The success rate of bone splitting with respect to a widening of the alveolar ridge, to enable consecutive implant insertion and implant healing, is stated to be over 90% (Chiapasco et al., 2006).

The main disadvantage of the conventional bone splitting technique is the risk of cortical wall fractures during separation, leading to bone necrosis and/or implant failure (Jamil and Al-Adili, 2017). Therefore in recent studies, the importance of minimally invasive procedures was highlighted, as bone degradation could be reduced to less than 1 mm in the area of the crestal bone, for example with the means of reduced flap mobilization or the usage of piezoelectric surgery (Jha et al., 2017; Gonzalez-Garcia et al., 2011; Jensen et al., 2009). Furthermore, an exact assessment of the bone and soft tissue anatomy, for example, identification of alveolar ridge concavities or consideration of the bone contour, seems to be of great relevance for the success of bone splitting in order to minimize intraoperative and postoperative complications.

Hence, we present a modified technique of bone splitting, which is based upon a precise patient-individualized preoperative planning by means of three-dimensional diagnostics and the use of surgical guide templates to enable reliable and minimally invasive bone splitting and bone spreading.

2. Material and methods

The modified technique is explained and supplemented by a clinical case. A 76-year-old female patient reported to the Department of Oral and Craniomaxillofacial Plastic Surgery of the University Hospital of Cologne, Germany with a chief complaint of missing teeth causing difficulty in speech and mastication. The patient did not have a history of smoking or any serious systemic disease.

The clinical situation and the panoramic view x-ray indicated a horizontal and vertical deficiency. To compensate the vertical deficiency, we planned a removable denture. Cross-sectional views of the CBCT (cone beam computed tomography) indicated the alveolar ridge as being 4 mm horizontally and 13 mm vertically (see Fig. 1). Furthermore the alveolar ridge was classified as a convergent type, thus requiring alveolar ridge expansion for adequate implant placement. The bone quality was classified as II, as she had a thick layer of compact bone surrounding a core of dense trabecular bone. Hence, the prosthetic goal in this case of a toothless upper jaw was an implant-supported (teeth number 15, 14, 12, 23, 24, 26) removable denture with telescopic crowns.

2.1. Stage I: Preoperative CBCT-based planning

The preoperative CBCT was transferred into a DICOM (Digital Imaging and Communication in Medicine) dataset in order to import it into the implant planning software coDiagnostiX® (Dental Wings Inc., Montreal, Canada). Within this software, we defined the splitting vector, comprising the information of the extension axis of the tooth position, and the direction of the surgical split, which needed to be in sufficient accordance with the prosthetic goal. We virtually planned with 3,8 mm implants (Camlog Srewline Promote Plus, Henry Schein), thus being normally sized and flush with the crestal bone. Then we aligned the implant position in such a way that it was centric in the alveolar ridge and regarded the required distance of

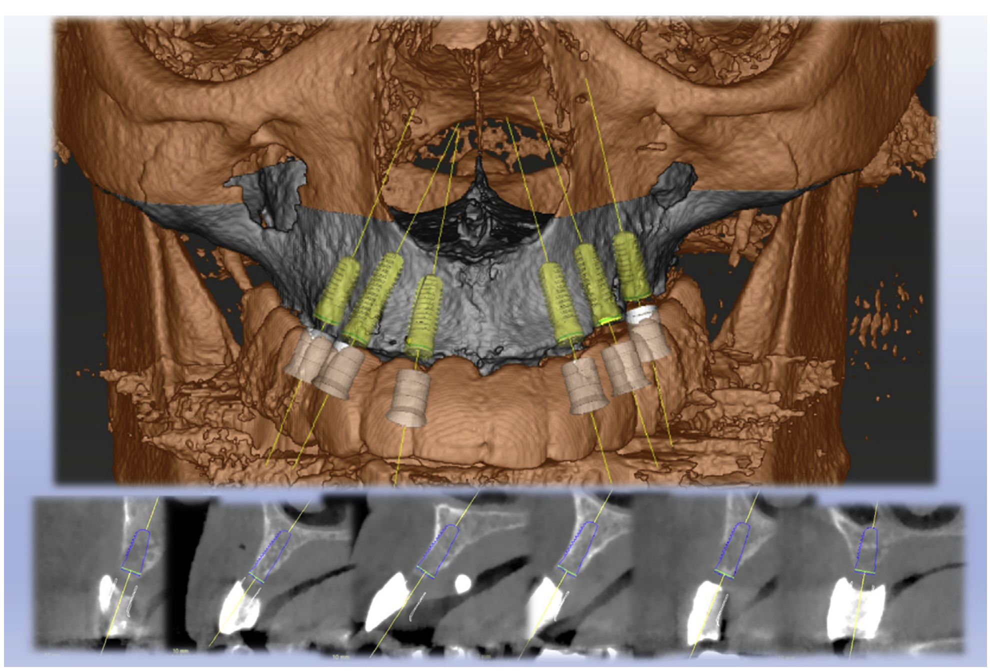

Fig. 1. Cross-sectional views of the CBCT (cone beam computed tomography) indicated the alveolar ridge was 4 mm horizontally and 13 mm vertically. To compensate the vertical deficiency a removable denture was planned.

1 mm to concavities and at the same time considered the prosthetic extension axis. This information was necessary to apply the splitting vector into the stereolithographic surgical templates (3D navigation control, Meisinger®, Neuss).

2.2. Stage II: Splitting by means of piezosurgery

The preliminary fabricated surgical template number 1 was used to perform several pilot millings with a narrow spiral mill (diameter 0.9 mm, Meisinger®, Neuss) to transfer the virtually determined splitting vector (see Fig. 2). Afterwards, a plotted cutting guide, based upon a slight palatinal incision behind the alveolar crest, was used to minimally invasively perform an incision and mobilize the soft tissue to raise a mucoperiosteal flap. Hence, an extensive representation of the bone situation was not required and vertical incision was only required in the anterior part. Due to the more favorable bone situation in the posterior region, no further vertical incision was necessary. This procedure also seemed more favorable for blood supply. Furthermore the palatinal periosteum was carefully protected to ensure adequate blood supply.

The piezosurgical osteotomy (OT 7S-3, 0.35 mm thickness and 3 teeth, Mectron® Germany, Cologne) was performed with the assistance of the surgical template number 2 (see Fig. 3) to maintain the correct splitting vector. This template had a guide surface along which the piezosurgery instruments could be guided exactly in the orientation of the virtually determined splitting vectors. The osteotomy was performed as deep as the subsequent implant lengths (range between 9 and 13 mm) and connecting sections between the pilot millings led to a complete bone split. Additionally, a longer mesio-distal osteotomy of the alveolar crest was performed.

2.3. Stage III: Full Guided bone expansion/spreading and implant insertion

Our third surgical template (see Fig. 4) was fabricated with sleeves, in order to guide expansion screws and spreading chisels. Ridge splitting until a gap of 3–4 mm was obtained, especially expanding the base of the alveolar ridge (Split-Control Professional, Meisinger, Neuss). Afterwards we carefully inserted the implants guided by the sleeves (Camlog® Screw-Line Promote plus) through the surgical template number 3 (see Fig. 5) (position 15: 9 × 3.8 mm; position 14: 13 × 3.8 mm; position 12: 11 × 3.8 mm; position 23: 11 × 3.8 mm; position 24: 11 × 3.8 mm; position 26: 9 × 3.8 mm). To fill the open space, we scraped autogenous bone from the zygomaticoalveolar crest with a microscraper. To reduce the infection risk, we closed the wound watertight with 5-0 non-resorbable polyamide (Resorba) sutures. Routine postoperative instructions were given. Chlorhexidine mouth rinse (0.2%) was prescribed for two weeks. Ibuprofen 400 mg with a maximal dose of 1200 mg per day was administered for 7 days. Amoxicillin 500 mg was prescribed three times daily for 5 days.

2.4. Stage IV: Postoperative care

Clinical monitoring was performed after 3 days, 1 week, 4 weeks and 3 months with a special interest to evaluate inflammation, wound healing disturbances, hypaesthesia, speech and mastication. After prosthetic rehabilitation, we followed up our patient for 2 years and could not observe any clinical (no obvious probing depth, no bleeding on probing) or radiographical complications (see Fig. 6).

3. Discussion

Numerous studies indicated alveolar ridge expansion osteotomy as a reliable and successful technique to obtain expansion within the intercortical space of the host bone, especially for patients with horizontal deficiency (Nguyen et al., 2016). The main advantages towards autogenous bone grafts and guided bone regeneration are on the one hand the reduced morbidity, as no second operation site is needed and on the other hand the lack of membrane or bone graft exposure risks (Kaneko et al., 2013). However, conventional alveolar ridge expansion osteotomy can be associated with problems such as perforation or even fracture of the labial cortical bone,

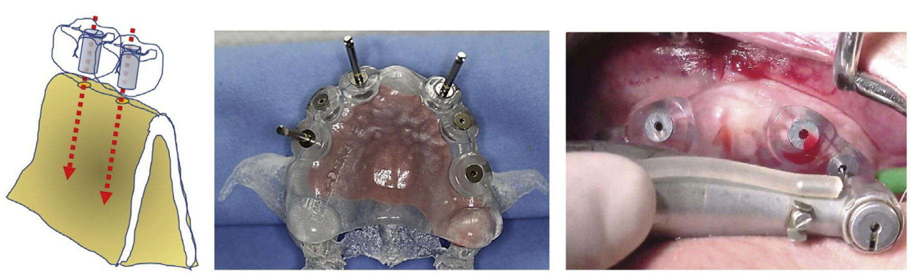

Fig. 2. Surgical template number 1 was used to perform several pilot millings with a narrow spiral mill (diameter 0.9 mm, Meisinger®, Neuss) to transfer the virtually determined splitting vector.

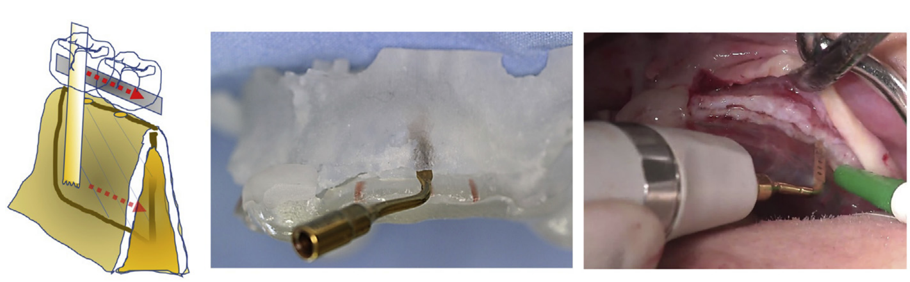

Fig. 3. Piezosurgical osteotomy was performed with the assistance of the surgical template number 2 to maintain the correct splitting vector. Template had a guide surface along which the piezosurgery instruments could be guided exactly in the orientation of the virtually determined splitting vectors.

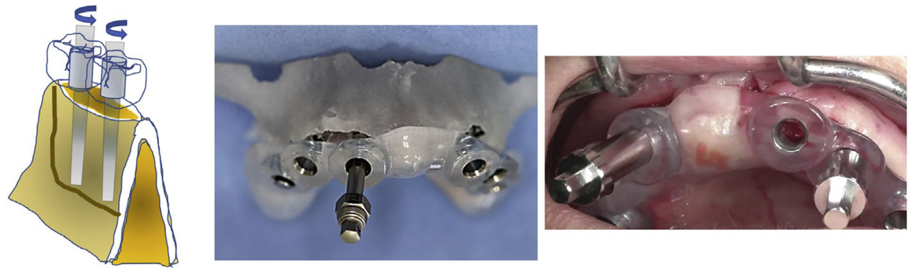

Fig. 4. Third surgical template was fabricated with sleeves, in order to guide expansion screws and spreading chisels. Subsequently, the implants were inserted through the guide sleeves.

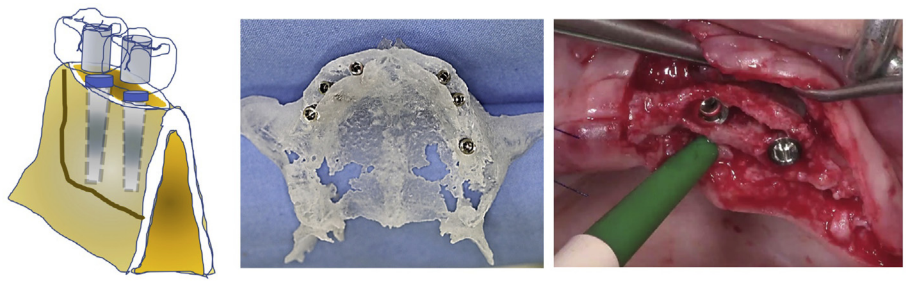

Fig. 5. Placed implants (Camlog® Screw-Line Promote plus), inserted through the guide sleeves of surgical template number 3.

making a simultaneous implant insertion impossible. The protocol for our modified, 3D based ridge expansion osteotomy reduces these risks, due to the clinical implementation of predetermined splitting vector, which allows guided bone splitting along a guide surface of the template in an ideal direction. Selected cases may benefit from the modified bone splitting technique for immediate and guided insertion of endosseous dental implants. The advantages of our modified 3D based full guided alveolar ridge expansion osteotomy protocol are listed in Table 1. Especially with the edentulous jaw, the support of the surgical guide templates is discussed in the literature: while the support on the bone surface is basically not considered necessary, a three-point support using auxiliary implants is recommended (Vercruyssen et al., 2014) (Van de Wiele et al., 2015). Also, the pure mucosal support of the surgical guide template is a favorable assessment (Cassetta et al., 2014). In the present case, favorable conditions exist for mucosal support, since the high palate and the medial mucosal support in one cm width, at the level of the papilla incisiva, counteracted movement of the template. To our knowledge there are none publications with matching of pre and post, if an inadequate bone reservoir necessitates augmentation for implantation. In the present case matching of preoperative simulation of implants with final implant position shows high precision for new method (see Fig. 7).

Fig. 6. Radiographic evaluation after healing period, with regular bone height situation, in region 26 with safely reduced bone density and bone height.

The principal shortcomings of alveolar ridge expansion osteotomy are patients with severe vertical defects and the necessity of cancellous bone within the edentulous ridge (Kaneko et al., 2013). However, we could observe that for our patient with combined horizontal and vertical defect, bone splitting was successful in terms of implant healing. We could compensate the vertical defect with a removable implant prosthesis. To obtain successful clinical outcomes, careful preparation of the intercortical space is a key factor for implant healing and expansion, due to the high osteogenic potential of the bone marrow. For bone splitting, a congruent alveolar ridge type is primarily suitable (Watanabe et al., 2010). A narrow parallel jaw type, which deviates from the ideal splitting direction may be unsuitable for bone splitting, whereas for alveolar ridges with undercuts, the position of the undercut is important (Nickenig et al., 2014). If the undercut (or the concavity) is not in the region of the planned expansion, for example below the mandibular canal, bone splitting might be performed (Nickenig et al., 2014). The radiological analysis of the affected region primarily takes place within the cross-section of the cone beam computed tomography (CBCT) images. The width of the crestal region should be at least 3–4 mm, so that at the level of the implant neck, the oral and vestibular cortical bone plates are approximately 1.5–2 mm thick (Nguyen et al., 2016; Jamil and Al-Adili, 2017). The background is a sufficient blood supply of the bone plates as well as the avoidance of a possible fracture (Jha et al., 2017). Hence, the virtual determination of an optimal splitting vector, corresponding ideally to the extension axis of the tooth position, is important. In virtual planning, a normally sized implant is used to correctly simulate the later clinical insertion. With a diameter of approximately 4 mm, the implant is therefore flush with the crestal bone.

As at least 1 mm of trabecular bone is necessary to maintain adequate blood supply after bone spreading, it is of utmost importance to use instruments for implant bed preparation that enable precise and thin alveolar ridge cuts (Jha et al., 2017). Gonzales-Garica et al. highlighted the advantages of piezoelectric

Table 1
Features of the 3D-based modified alveolar ridge expansion.

Successive application of surgical guides for incision, ridge osteotomy, expansion and implant insertion
Predetermined splitting vector allows guided bone splitting along a guide surface of template in an ideal direction
Less cortical bone fractures and perforations because of virtually determined splitting vector
Longer mesio-distal osteotomy of the alveolar crest
Simultaneous and guided insertion of the implants

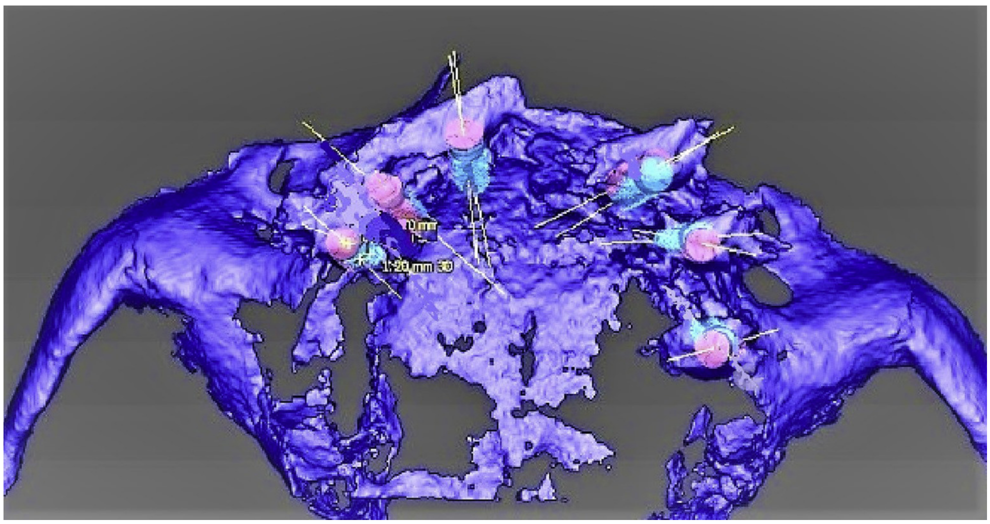

Fig. 7. Matching of preoperative simulation of implants (light blue) with final implant position (red) shows high precision for the new method (difference in angulation between 2,2° (implant 12) - 5,8° (implant 26)/difference in 3-D position between 0,56 mm (12) until 0,85 mm (23).

surgery for alveolar expansion osteotomy and observed not only the aforementioned advantages but also less tissue damage and vibration compared to surgical saws and burs (Gonzalez-Garcia et al., 2011). This in accordance with our findings, as no major complications, for example buccal cortical plate fracture, explantation or disrupted wound healing, has been observed by using piezoelectric osteotomy and bone expanders. A recently published study by Jha et al., in 2017 demonstrated in a systematic review that piezoelectric devices should be preferred over conventional burs and saws to prevent any trauma to the vulnerable structures like mucosa, nerves and blood vessels (Jha et al., 2017).

Cortical bone fractures are a rare event when using minimally invasive bone splitting techniques, especially when avoiding vertical bone incisions and relieving cuts (Milinkovic and Cordaro, 2014). In most cases, the segment is not entirely fractured, as it is often fixed on one side or apically (Nickenig et al., 2014). In these cases, the bone plate can be screwed to the gap using osteosynthesis screws. The open space area is then filled with autogenous bone or bone substitute materials. A cover with membrane can be indicated in these cases. Regarding the filling of the resulting gap, there are different opinions, as on the one hand it is assumed that the regenerative potential of the bone marrow is sufficient for defect replenishment and on the other hand in animal models it was found that filling the gap with bone substitute material and additional application of a membrane led to favorable bone-implant contact after simultaneous implantation (Han et al., 2011).

Our results show that patient-individualized preoperative computer-assisted planning and usage of individualized CBCT-based templates are associated with a high functional and aesthetic outcome, especially in the maxillary anterior area, which presents an aesthetic zone. In the present case, a prosthesis in a dentoalveolar (bridge) design could be implemented. Facial bone perforation was not detected in our patient, although the narrow alveolar ridges demonstrated a clinically challenging situation. We observed a bone gain of 4–5 mm. This is in line with previously published data, as for example Jamil et al. reported a maximum gain of 7 mm (Jamil and Al-Adili, 2017).

Hence, we assume that the successful clinical outcome can be attributed to the precise and patient-individualized preoperative planning, the use of surgical templates, and piezoelectric surgery, which minimized trauma and simplified the splitting procedure.

4. Conclusions

With the described modified bone splitting technique, the implants were well osseointegrated and no wound healing disturbances or any other complications were observed. We consider the modified, full-guided bone splitting technique is an effective treatment method for atrophic jaws and the placement of dental implants. Especially, individualized preoperative planning helps to minimize complications. However, long-term outcomes and a study, conducted on a study group, is needed to evaluate the benefits of our presented treatment protocol.

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