The Reconstructive Potential of Distraction Osteogenesis on Defects of the Alveolar Ridge Before Dental Implants Placement: A Review

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Abstract: Nowadays, distraction osteogenesis is being widely used for increasing the height of the alveolar ridge before the placement of dental implants. Distraction osteogenesis can be considered as an alternative to many other augmentation techniques. Compared with the conventional techniques of bone grafting and guided bone regeneration, alveolar distraction osteogenesis seems to have significant advantages such as, lower infection rate, no donor site morbidity and gain of soft tissue. It can be achieved by intraosseous or extraosseous devices and the whole procedure includes the latency phase, the distraction phase and the consolidation phase. Despite the referred advantages, the technique still has significant limitations. Consequently, alveolar distraction osteogenesis cannot be considered as an uncomplicated procedure. However, complications related to this technique are mainly minor and can be solved with simple treatment. According to many studies, it can be concluded that although, distraction osteogenesis is an effective surgical procedure to treat vertical alveolar deficiencies, especially before implant placement, there is a need for more clinical studies on implants placed in distracted alveolar bone based on long-term follow-up.

Keywords: Distraction osteogenesis, alveolar ridge, bone defect, bone augmentation, oral surgery, dental implants

INTRODUCTION

Dental rehabilitation of partially or totally edentulous patients with dental implants has become popular in the last decades, with reliable long-term results. Success rates for dental implants averages ~90% (Lekholm et al., 1999; Buser et al., 1997; Adell et al., 1990; Albrektsson et al., 1988; Rachmiel et al., 2001a). However, one of the most common and principal problems in dental implantation is the lack of appropriate bone height or width (Saulacic et al., 2004) in mandible and maxilla. Alveolar defects can be acquired or congenital. Acquired alveolar defects are classified into vertical and horizontal and may be caused by post-extraction defects, periodontal disease and traumatic avulsion of teeth or after tumor resections. The nature of the deficiency may prevent the ideal implant positioning by compromising aesthetic and prosthetic needs (Rachmiel et al., 2001a). Furthermore, insufficient alveolar ridge height impedes the use of implants of sufficient length, giving an inadequate crown-to-implant length ratio (Saulacic et al., 2004). It has been demonstrated that short implants fail more frequently than longer implants (Frieberg et al., 1991). However, the ability to regenerate maxillary and mandibular bone using augmentation techniques and methods has extended the range of implant treatment. A variety of surgical procedures have been proposed for alveolar ridge reconstruction, such as autogenous bone grafting (Lindgren et al., 1997; Neyt et al., 1997; Bell et al., 2002; Jennt and Lekholm, 2003; Chiapasco et al., 2007a), vertical Guided Bone Regeneration (GBR) (Simion et al., 1994, 2001; Jovanovic et al., 1995; Chiapasco et al., 2004a) and use of alloplastic materials (Caplanis et al., 1997; Jerssen et al., 1995).

Recently, a useful tissue-engineering technique that allows the height of the alveolar ridge to be increased effectively, has gained increasing acceptance, namely alveolar Distraction Osteogenesis (DO) (Jerssen et al., 2002; Mazzonetto and Allais de Maurette, 2005). Nowadays, it is being widely applied for the treatment of alveolar ridge atrophy, before the placement of dental implants and may be considered as an alternative to many other augmentation surgical procedures. Compared with the other conventional techniques of bone grafting and guided bone regeneration, alveolar distraction osteogenesis has remarkable advantages such

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as decreased bone resorption, lower infection rate and no donor site morbidity (Horiiuti et al., 2002; Rachmiel et al., 2001a; Urbani, 2001) and gain of soft tissue (Horiiuti et al., 2002; Raghoebear et al., 2000; Jønssen et al., 2002). The disadvantages include difficulty in controlling the segments, lack of patient cooperation, the need for more office visits and the cost of the device (Garcia-Garcia et al., 2002b; Uckan et al., 2002b; Van Strijen et al., 2003).

The first description of distraction osteogenesis was by Codivilla (1905) when, after femoral osteotomy, he subjected the fragments to a strong tension using nails fixed in the bone. However, the Russian physician Gabriel Abramowitch Ilizarov (1989a, b) was responsible for the great development in this technique in the 1950s, with the design of new distraction devices and studies of distraction rates. The technique relies on stretching the bones to achieve lengthening and new bone regeneration (Jönsson and Stenås, 1998). Ilizarov (1989a, b) performed numerous experiments in dogs and advanced the clinical utility of this technique. He, also, established two basic principles of distraction osteogenesis that are the law of tension-stress and the influence of mechanical load and vascular supply. These basic principles have three distinct phases: a latency phase of approximately 7 days of initial post surgical healing, the distraction phase, consisting of the gradual incremental separation of two bone pieces at a rate of approximately 1 mm day^{-1}, consolidation phase, during, which new bone is formed in the regeneration zone between the separated bone pieces (McAllister and Gaffaney, 2003).

Alveolar distraction osteogenesis in dogs was firstly reported by Block et al. (1996). In the same year, Chin and Toth (1996) described the first alveolar distractor applied to alveolar defects on humans, after traumatic tooth losses. Subsequently, distraction osteogenesis was applied in the mandible (Guerrero, 1990; McCarthy et al., 1992) as well as in the maxilla and vertically deficient alveolar ridge (Chin and Toth, 1996). Recently, it has been shown that alveolar distraction osteogenesis can be considered as a predictable and effective method for vertical augmentation of resorbed alveolar ridges (Chiapas et al., 2004b; Jønssen et al., 2002; Polo et al., 2005).

Various distraction devices are now available for oral and maxillofacial application, including mandibular, maxillary, midfacial, cranial and alveolar distractors (Cano et al., 2006). Distraction osteogenesis can be achieved by introsseous (Gagg et al., 1999; Garcia-Garcia et al., 2003) or extratarsous devices (Chiapas et al., 2004b). The widest clinical studies have been performed on 3 alveolar distractor designs: TRACK extra-bone distractor (Tissue Regeneration Alveolar Callus distraction; Kohn Martin, Tutlingen, Germany) (Chiapas et al., 2001), HEDLEAD intra-bone distractor (Leibinger Endosseous Alveolar Distractor; Stryker-Leibinger, Freiburg, Germany) (Chi, 1999a) and DISSIS implant-distractor (Distraction Implant System; SIS, Klagenfurt, Austria) (Gagg et al., 2000b).

Despite of all the referred advantages of alveolar distraction osteogenesis, both basic and clinical research demonstrates that this technique still has significant limitations (Mercier, 2004). After all these years of extended application of alveolar distraction osteogenesis there is still significant divergence about various treatment parameters, such as surgical procedure, type of distractor and minimal bone height necessary to perform the distraction. There is a lack of evidence regarding the appropriate distraction osteogenesis protocols, maximum augmentation volume and long-term implant success rates (Saulacoc et al., 2008). Furthermore, alveolar distraction osteogenesis cannot be considered as an uncomplicated procedure. However, the complications related to this technique can be solved with simple treatments (Gnabey et al., 2008).

The aim of this study is to evaluate the osteogenic potential of distraction osteogenesis on defects of the alveolar ridge, in order to achieve aesthetic and functional restorations and thus to provide some information about the survival and success rates of implants placed in distracted areas.

MATERIALS AND METHODS

The effect of distraction osteogenesis on vertical ridge augmentation, before the placement of implants on the success rate of implants, has been investigated by many scientists in the last few years. Rachmiel et al. (2001b) applied distraction osteogenesis to 14 patients aged from 17-55 years old with edentulous alveolar ridge, 8 in the mandible and 6 in the maxilla (Rachmiel et al., 2001b). Vertical alveolar bone distraction was started by performing a segmental alveolar osteotomy followed by insertion of a central distraction device. Lead System (Endosseous alveolar distraction system, Leibinger). The latency phase lasted three days. After this period, distraction was started in a rate of 0.8 mm day^{-1} for 9-16 days as needed. Retention phase for new bone maturation was twice as long as the active distraction phase. After removal of the device, 23 cylindrical threaded implants were inserted. Results showed increase of the alveolar bone height with new bone formation that was observed radiographically and clinically at the removal of
the device. They achieved an elevation of 7-13 mm. In a follow-up of 6-14 months, failure of only one implant was noted, due to inadequate transported bone stability.

Another study on a sample of 8 patients examined the potential of intraoral distraction osteogenesis to vertically elongate insufficient alveolar ridges for ideal implant placement (Chiapasco et al., 2001). These patients were treated by means of distraction osteogenesis principles with an intraoral alveolar distractor. About 2-3 months after consolidation phase, 26 implants were inserted in the distracted areas. Four to 6 months later, the abutments were positioned and prosthetic loading of implants was started. The mean follow-up after initial prosthetic loading was 14 months. In all patients, the desired bone gain was reached at the end of distraction (mean vertical bone gain of 8.5 mm). Cumulative success rate of implants was 100%. Radiographic examinations 12 months after functional loading of implants revealed a significant increase in the density of the newly generated bone in the distracted areas.

Recently, Saulacic et al. (2007) designed a retrospective study in order to evaluate the volume of hard tissue generation at the time of implant placement in distracted alveolar bone. In this study, all patients who underwent distraction osteogenesis between 2000 and 2003 were included. Preoperative bone height, amount of distraction performed and presence or absence of complications were recorded. The study included 43 implants placed in 17 cases of alveolar distraction. Of the 34 implants placed in bone augmented by 4.5-6.5 mm, bone defects were observed with 12. All 9 implants placed in ridges augmented by 7-10.5 mm demonstrated a bone defect. The defect and no defect implant groups differed significantly with respect to preoperative bone height and amount of distraction performed. Significantly, more defects were formed in bone augmented by >25% compared to bone augmented by <25%. Scientists concluded that, when considering distraction osteogenesis, augmentation of up to 25% of the initial bone height seems more predictable and less likely to be associated with complications at the time of implant placement. In distractions >25% of the original height, additional treatment should be considered.

According to Kanno et al. (2007) a decrease in bone height after alveolar distraction osteogenesis and before implant placement is common and can be severe when distraction osteogenesis is performed soon after surgical intervention. They investigated the decrease in bone height after vertical DO and determined the need for overcorrection with implant placement. Thirty-five patients (17 males and 18 females, with mean age of 43.9 years) underwent 38 procedures with successful placement of 141 dental implants. Alveolar ridge height was evaluated using digital orthopantomographic radiographs, taken shortly after the end of distraction phase, at consolidation phase and before implant placement. The mean distraction was 9.7 mm. Total vertical alveolar bone decrease was 2.1 mm (21%) during the consolidation phase and 3.6 mm (37%) at implant placement. Although, the 20 sites with a healthy alveolus (surgery >6 months) had bone reductions of 1.5 and 2.5 mm (15 and 25%) the 18 sites at which alveolar DO was performed within 6 months (mean 3.0) of surgical intervention had much greater bone loss of 2.7 and 4.8 mm (28 and 50%). Subsequently, the researchers indicated that any alveolar DO protocol should include a waiting period after the surgical intervention, as well as consider an overcorrection of >25% within the limits of the applied surgical protocol.

In addition to the above mentioned, an investigation was performed by Uckan et al. (2002b) in order to evaluate the intraoperative and postoperative complications of alveolar distraction. Ten patients with alveolar ridge deficiencies were treated with DO by means of intraosseous distractors. Deficiencies were caused by atrophy after tooth extraction, benign tumor resection, trauma, or oligodontia in a case of ectodermal dysplasia. The location of the defects was the anterior mandible, posterior mandible and anterior maxilla. The follow-up was 1.8 years, with a range of 10 months to 3 years. The mean alveolar distraction achieved in 10 cases was 8.7 mm (5-15 mm). The intraoperative and postoperative problems encountered were lingual and palatal displacement of the distracted segment, fracture of the distracted segment when there was a very thin alveolar bone and intraoperative bleeding. According to them, overall complication rate was 70%. However, most of the complications were minor and eliminated easily. Implant success rate was 85%.

A special study was, recently, conducted by Perez-Sayans et al. (2008) to evaluate bone resorption around implants, placed in alveolar bone subjected to distraction osteogenesis. Nine patients underwent alveolar DO with subsequent placement of 37 implants. None of the implants was lost. Vertical peri-implant bone deficit was measured on the distal and mesial surfaces according to the examination of panoramic radiographs, obtained at the time of implant loading and again, 1 year later. Resorption over the year of loading was calculated as the increase in vertical bone deficit. The results of this investigation showed that vertical bone resorption around implants placed in distracted alveolar bone is similar to that seen around implants placed in nondistracted bone.
DISCUSSION

There are many reconstructive and regenerative techniques for augmentation of the alveolar ridge. These methods include autogenous bone grafting, guided bone regeneration and the use of alloplastic implants, xenografts and allografts (Satow et al., 1997; Triplett and Schow, 1996; Caplanis et al., 1997; Jenssen et al., 1995). Today, distraction osteogenesis is being widely used for alveolar ridge augmentation (Garcia-Garcia et al., 2002a). In the context of implantology, the aim of alveolar distraction osteogenesis is to create new bone and adequate volume of soft tissues, ensuring sufficient height and/or width of the alveolar ridge for accurate implant placement (Chin, 1999b; Sauliac et al., 2004; Vejar et al., 2000). Distraction osteogenesis was subsequently applied to the vertical expansion of the alveolar bone with good experimental and clinical results (Chin and Toth, 1996; Block et al., 1996; Oda et al., 2000; Jenssen et al., 2002; Horiuchi et al., 2002; Nosaka et al., 2002). The main advantage of the vertical bone distraction is that there is an increase in alveolar bone height with new bone formation beneath the distracted bone. In addition to this, simultaneous thickening of surrounding soft tissues is achieved by histogenesis (Garcia-Garcia et al., 2002b; Chiapasco et al., 2001; Gagel et al., 2000c). As it has been referred above, distraction osteogenesis can be achieved with intrasosseous (Gagel et al., 1999; Garcia-Garcia et al., 2003) or extrasosseous devices (Chiapasco et al., 2004b). Compared with extrasosseous devices, whose main components are placed on the surface of the bone, intrasosseous devices have several advantages, including the capability of distracting the extra-small bone segments, without requiring any pins or plates to hold the distractor in place and being a better tolerated device by patients because of their small dimensions (Urbani, 2001; Yalcin et al., 2006). However, Gunbay et al. (2008) disagree with the last claim, since their patients tolerated both types of the distractors.

Successful surgical correction of vertically deficient alveolar ridges, followed by rehabilitation with implant-supported prostheses has been reported for both autogenous bone grafts (Lundgren et al., 1997; Iizuka et al., 2004; Van der Meij et al., 2005) and alveolar distraction osteogenesis (Gagel et al., 2000b; Rachmiel et al., 2001a; Jenssen et al., 2002; Chiapasco et al., 2001, 2004a, b). Both techniques present their advantages and limits. Vertical DO presents lower postoperative morbidity, but on the other hand it has greater limitations of use and presents a relevant incidence of vector changes that may compromise the final outcome (Chiapasco et al., 2007b). Consequently, there is a need of more comparative studies in order to demonstrate whether one technique is better than the other. Furthermore, Chiapasco et al. (2004a) compared the results of vertical guided bone regeneration with distraction osteogenesis. They found that bone resorption values, before and after implant placement, were significantly higher in the GBR group. Additionally, the success rate of implants placed to patients treated with DO, was higher than that obtained to patients treated with GBR.

Kanno et al. (2007) observed, a decrease in bone height following alveolar distraction osteogenesis, before implant placement. However, only a few clinical reports have mentioned the possibility of bony relapse following DO in the maxillofacial and alveolar regions (Chiapasco et al., 2004b; Sauliac et al., 2005; Van Strijen et al., 2004). It has been suggested that overcorrection might be beneficial. According to some previous studies, overcorrection could be useful and effective for various implants and for preventing bone relapse with alveolar DO (Hidding et al., 1999; Klesper et al., 2002; Raghoebarsing et al., 2002; Sauliac, 2005). While, some instability was noted in terms of alveolar DO, sufficient overcorrection should solve this problem and eliminate any functional problems regarding dental implant placement (Kanno et al., 2007).

With regard to the complications related to distraction osteogenesis, the total percentage of the complications, in the literature, ranges from 0% (McAllister, 2001) to 100% (Garcia-Garcia et al., 2002a). Complications that may occur during alveolar distraction have been classified by Garcia-Garcia et al. (2002b) into three groups: problems arising during surgery, generally related to osteotomy and distractor placement; complications arising during distraction, including incorrect direction of distraction and soft-tissue complications and complications arising after distraction, due to defective bone formation. Uckan et al. (2002a) reported bleeding in cases of deep osteotomy, pain and significant resorption of the distracted fragment in distractions of >10 mm. Other complications such as dyesthesia of the mental nerve and mandibular fracture have, also, been described (Klug et al., 2000; Gagel et al., 2000a; Nocini et al., 2000). However, most complications arising during distraction osteogenesis can be considered minor and are readily resolved (Sauliac et al., 2004). Despite all the complications referred above, dental implants can be safely inserted into distracted areas in most instances and long-term survival of loaded implants is satisfactory (Enisildis et al., 2005).
With reference to the three distinct phases of distraction osteogenesis, there are not yet established protocols for alveolar bone distraction. There is a trend to a reduction in latency times, by scientists, based on the better vascularization of the jaw bones. Although, a latency phase is not strictly necessary for bone regeneration, a latency time of 5-7 days is desirable to obtain a mucosal closure of the wound and avoid dehiscences or communications in the distraction chamber (Cano et al., 2006). About the distraction phase, most experimental and clinical studies used a distraction index of 1 mm day^-1, activating the distractor 2 or 3 times/day (Iliarov, 1989b; Troulis et al., 2000; Chiapasco et al., 2007b; Perez-Sayans et al., 2008). As for the consolidation phase, there is a tendency to withdraw the distractor as soon as possible in order to avoid infectious complications and allow early implant placement, before the distraction chamber is completely mineralized. Moreover, Cano et al. (2006) claim that the distractor should be maintained for the minimum time necessary to achieve a tissue that is biomechanically resistant to implant placement. They also, consider that in the future, the duration of each distraction phase will depend on the circumstances of each individual and will take account of the patient age, type of bone, general health status and genetic diagnosis, among other factors. However, the duration of consolidation phase seems to be the major factor that determines the duration of the overall treatment period and performance of implants placed (Saulacic et al., 2008).

CONCLUSION

Distraction osteogenesis is an effective surgical procedure to treat vertical alveolar ridge deficiencies. Many scientists have shown that alveolar DO is a reliable technique without major complications such as infection and has better long-term prognosis and stability, especially after implant placement, than the conventional guided bone regeneration and bone transplantation techniques (Chiapasco et al., 2004a, b; Garcia-Garcia et al., 2003; Saulacic et al., 2004; Van Strijen et al., 2004). However, there have been only a few published clinical studies on implants placed in distracted alveolar bone based on long-term follow-up. Application of different treatment modalities may be significantly beneficial to the patient, to enhance the quality of distracted bone, shorten the overall treatment period and improve the performance of implants placed in distracted alveolar ridges.

REFERENCES


