CHAPTER 6

State of the art of techniques and instruments used to obtain primary stability in osseointegratable implants

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ABSTRACT

The drills used in the osseodensification (OD) technique have a short clinical and scientific history, with little information in the literature regarding the actual bone compaction achieved, in relation to the different designers and methodologies of each system. Objective. This integrative literature review aimed to discuss the state of the art of techniques and instruments used to obtain primary stability in osseointegrated implants. Materials and methods. Patent applications and works were selected from the scientific research bases of Scielo, Pubmed, lilacs, Google Scholar, Google patents and books, using the key words, in Portuguese and English: “primary stability”, “bone densification”, “osseodensification” and “bone implant contact”. Results. A total of seventy-seven articles were compiled, which had information on the techniques and instruments used to obtain primary stability in osseointegrable implant surgeries. Conclusion. Osseodensification suggested advantages over other bone densification techniques, such as ease of insertion of instruments and obtaining bone-implant contact with greater bone density. However, further studies are needed to enable longitudinal evaluations in order to verify the success of osseointegrated implants installed using this technique.

Keywords: Osseodensification bone osteotomy, Endo-osseous dental implant, Primary stability, Bone-to-implant contact.

1 INTRODUCTION

In the 1960s, Brånemark defined osseointegration as a histological process in which there is a direct structural and functional connection between living, organized bone and the surface of an implant, which is subjected to a functional load, and must remain for three to six months without receiving occlusal loads (BRANEMARK *et al*., 1983). Subsequently, LEKHOLM & ZARB (1985) reported that immediate loading could be achieved by obtaining primary stability in type I, II and III bones, with type I bone being composed mostly of a thick cortical bone, while type II has a significant amount of cortical bone surrounding a cancellous bone, and type III bone. There is a small layer of cortical bone surrounding a bulky cancellous bone. Type IV bone, on the other hand, contraindicated for immediate loading, is characterized by the presence of a very thin or almost non-existent layer of cortical bone surrounding a low-density bone.

In this aspect, the cortical bone has a greater capacity for resistance to load, due to the greater capacity to absorb forces, while the medullary bone has less resistance and greater dissipation of forces due to its structural shape. Therefore, as a result of these biomechanical characteristics, different studies have indicated the need for greater anchorage of the implant near the cortical bone region (HANSSONA & WERKEB, 2003; THOMÉ *et al.*, 2008; LEE *et al.*, 2010; ELIAS & SOARES, 2021).

1.1 ALVEOLAR ATROPHIES

The morphology of the bone defect is an important consideration in the selection of the alveolar ridge reconstruction technique for an adequate therapy with integrated bone implants, and techniques can be used to achieve ridge augmentation (MANSO, 2002; DOLANMA *et al.*, 2015). In this context, the traumatic loss of alveolar bone, caused accidentally or iatrogically, may result in resorptions with similar extensions (BAYS, 1986), resulting in a reduced bone volume remaining in the alveolar ridges after tooth loss, depending on the extent of the traumatic injury and/or the alveoloplasty technique employed (KEITH Jr & SALAMA, 2007; AIMETTI *et al.*, 2009; ALHEZAIMI, 2010; MOYA-VILLAESCUSA & SÁNCHEZ-PÉREZ, 2010).

SEIBERT (1983a, b) described and classified alveolar ridge defects, dividing deformities into three categories. In Class I, the alveolar ridge presents vestibulolingual bone loss with normal apico-coronal height, whereas in Class II, the ridge presents coronal apical bone loss with normal vestibulo-lingual thickness, and in Class III, the alveolar ridge presents a combined loss in both the vestibulo-lingual and apico-coronal directions, resulting in a reduction in thickness and height.

Subsequently, Lekholm & ZARB (1985) proposed a classification aimed at quantifying the bone defects present in the alveolar ridge, as well as their quality. Regarding this last factor, the authors described four types of alveolar ridges, ranging from those that were totally corticalized to those where there was a predominance of medullary bone, as follows: Type A, virtually intact alveolar ridge; Type B, minimal residual ridge resorption; Type C, advanced resorption of the residual ridge to the basal bone; Type D, initial resorption in the basal bone and Type E, extreme resorption in the basal bone.

Specifically in relation to atrophic maxillae, FALLSCHÜSSEL (1986) classified these defects as: Class 0, toothed ridge; Class I, high honeycomb process with great thickness; Class II, high honeycomb process and low thickness; Class III, high and bladed alveolar process, Class IV, wide alveolar process with reduced height and Class V, fully resorbed alveolar process. Subsequently, MISCH & JUDY (1987) presented classifications of maxilles and mandibles of partially edentulous patients, establishing four basic divisions in relation to the amount of bone available, in maxilla and mandible, for implant dentistry, including: Division A, edentulous ridge with adequate height and width; Division B, adequate bone height, but with decreased thickness; Division C, edentulous ridge with moderate resorption, and Division D, severe ridge atrophy with basal bone loss.

CAWOOD & HOWELL (1988) performed a classification based on random sections of 300 dried skulls. This classification aimed to simplify the description of edentulous alveolar ridges, directing to the best surgical-prosthetic method to be used, being the dentate alveolar ridge, Class I; o immediately after extraction, Class II; the rounded honeycomb border, with adequate height and thickness, Class III; the knife-edge honeycomb edge, with adequate height but inadequate thickness, Class IV; the flat alveolar ridge, with inadequate width and thickness, Class V, and the depressed alveolar ridge, with some evident loss of basal bone, Class VI.

1.2 STABILITY

The concept of dental implant stability has been subdivided into primary and secondary stability (SENNERBY & MEREDITH, 1998), with primary stability defined as the primary fixation occurring in the immediate insertion of the implant into its socket, dependent on the surgical procedure and bone quality and quantity, as well as the macrogeometry and surface of the implant (SENNERBY & MEREDITH, 1998; NEDIR *et al*., 2004; NOGUEROL *et al.*, 2006; DILEK *et al*., 2008; CHO *et al.*, 2009*;* SEONG *et al*., 2009; GEHRKE *et al*., 2019; DI STEFANO *et al*., 2019; ATIEH *et al*., 2021; ELIAS & SOARES 2021; GEHRKE *et al*., 2023). In relation to implants, primary stability depends on different macrogeometric characteristics, in the composition and treatment of their surface, and one or more of these characteristics increase the biological response of the tissue on the implant surface, leading to an increase in the success or survival rate (MEREDITH, 1998; SANTOS *et al*., 2013; PONZONI *et al*., 2018; DI STEFANO *et al*., 2021; ELIAS & SOARES, 2021; GEHRKE *et al*., 2023).

The objective of achieving primary stability corresponds to the fact that it is considered the appropriate condition to result in an immediate loading, leading to the success of an implant system (ROMANOS *et al*., 2002). The ideal values for an immediate load are established between 25, 32 and 45 Ncm of torque (ROMANOS *et al*., 2002; LORENZONI *et al.*, 2003; LAGES *et al*., 2018; MAKARY *et al*., 2019; LEMOS *et al*., 2020). On the other hand, MISCH (2006) stated that the success in primary stability consists in the preparation of the bone bed slightly smaller than the structural dimensions of the implant to be installed, with insertion torques above 40 Ncm. Thus, the contact of the walls of the larger implant with the smaller surgical bed would favor the stability necessary for the osseointegration process. Bone density should be considered as the most important factor for the fixation of an implant in order to achieve initial stability and absence of movement during the early stage of surgical healing (HUWAIS & MEYER, 2017; ALMUTAIRI *et al*., 2018; RAUBER, 2019; BERGAMO *et al*., 2021).

LIAJE *et al*. (2012) stated that one of the prerequisites for osseointegration is primary stability, determined by the degree of mechanical fixation of the implant to the bone, and it depends on macroengineering and the bone *implant contact* area (BIC), factors such as the ratio between cortical and cancellous bone and the surgical technique. As a result of bone remodeling and biological fixation in the BIC, there is a process of osseointegration, establishing secondary stability. Therefore, the factors related to implant stability are bone quality and quantity, surgical technique, and bioengineering, which can influence the implant activation time for each individual situation (LIAJE *et al*., 2012; BALDI *et al*., 2018; DI STEFANO *et al.*, 2021; MELLO-MACHADO, 2021; ELIAS & SOARES 2021; GEHRKE *et al.*, 2023).

Therefore, this integrative literature review aimed to discuss the state of the art of the techniques and instruments used to obtain primary stability in osseointegrated implants.

2 MATERIALS AND METHODS

Patent applications and papers were selected from the scientific research databases of Scielo, Pubmed, lilacs, Google Scholar, Google patents and books, using the keywords, in Portuguese and English: "primary stability", "bone densification", "osseodensification" and bone implant contact.

3 RESULTS

According to the research carried out, a total of seventy-seven articles were compiled, which provided information on the techniques and instruments used to obtain primary stability in osseointegrated implant surgeries.

3.1 TECHNIQUES FOR ACHIEVING PRIMARY STABILITY

Some methods are employed to increase the stability of the implant, aiming to achieve maximum predictability and safety in implant success, such as the underpreparation of the implant bed, osteal expansion, Summers' osteotome technique and Meisinger's controlled bone expansion technique (AL GHAMDI, 2009; KANATHILA & PANGI, 2018).

3.1.1 Implant bed under-preparation

A widely used method to increase primary stability is to under-prepare the implant bed, which is achieved by using drills with smaller diameters than the implant diameter. In the presence of poor bone quality, a 10% reduction in implant bed diameter is sufficient to improve primary stability, while further reductions do not improve primary stability values (KANATHILA & PANGI, 2018). On the other hand, BRILAN *et al*. (2010), concluded that the undersizing of the implant bed optimizes primary stability, especially when the implants were placed in trabecular bone. The logical principle underlying this technique corresponds to the idea that the implant itself will partially compact the bone as it is inserted and, therefore, would improve the primary stability, resulting in the improvement of the initial BIC, due to the compression of the fine trabeculae. The use of this approach depends on the initial bone density, since the softer the bone, the fewer drills are needed, and the larger the diameter of the implant used, the greater the increase in compression, favoring primary stability. In this concept, a high compression of the osteotomy can result in osteolysis (TELLES *et al*., 2014).

3.1.2 Osteo expansion

Alveolar atrophy represents a challenge for the installation of dental implants, being correlated with tooth loss, iatrogenesis, accidents, trauma after tooth extraction or infection, resulting in an alveolar ridge with deficient height and/or width for the installation of dental implants (NISHIOKA & SOUZA, 2009).

The technical solution to this structural obstacle is bone expansion, using bone expanders or osteotomes or a known "*split-crest*" approach (SCIPIONI *et al*., 1994, JENSEN & TERHEYDEN, 2009). The latter is the enlargement of the atrophic ridges with chisels, causing a fracture in a green branch and lateral bone compaction, resulting in an increase in the bone width of the atrophic ridge. TATUM (1986) was the first dentist to develop a specific technique of bone expansion, however it was SUMMERS in 1994 who developed not only the technique, but also produced the instruments necessary for its manufacture, known as Summers' osteotomes and modified osteotomes, for very narrow ridges (SUMMERS, 1994a; SUMMERS, 1994b; SUMMERS, 1994c).

This technique makes it possible to install implants in the same surgical procedure, reducing the number of surgical procedures, in addition to not requiring a donor area for graft removal, which reduces morbidity and the complication rate for patients (WAECHTER *et al*., 2017; GONZÁLES-GARCIA *et al*., 2011; TENG *et al*., 2014). Therefore, this technique is less invasive than bone grafts, providing a reduction in trauma for simultaneous implant placement (NISHIOKA & SOUZA, 2009), which should have a slightly larger diameter than the site created by the expander (SCIPIONI *et al*., 1994). With each expander inserted, the bone is compacted laterally and the range of its horizontal dilation is controlled and standardized (NISHIOKA & KOJIMA, 2011). Therefore, after compression of the bone medullary wall against the cortical walls, there is the creation of a bone expansion of the buccal wall, resulting in a notable improvement in bone density and primary stability of the implant installed (NISHIOKA & KOJIMA, 2011).

3.1.3 Summers' osteotome technique

The osteotome technique of Summers (1994), composed of the instruments of the same name, would generally be used for immediate insertion of implants. The technique proposed that the insertion of the osteotome would compress the bone laterally, displacing the particles towards the floor of the breast (SUMMERS, 1994a; SUMMERS, 1994b). Expansion with the use of osteotomes has proven to be a reliable and non-invasive technique to correct narrow edentulous ridges, promoting lateral apical bone compression and resulting in an increase in local bone density (AL GHAMDI, 2009).

Summers' osteotomes have the following characteristics: the No. 1 osteotome with a diameter of 1.6 mm at the tip, so as to penetrate the bone easily. No. 2, with 2.4 mm at the tip, to be inserted at the site of the osteotomy already created by No. 1. And the remaining osteotomes would be proportional, in a similar way, up to No. 5, used for implants of 5.0 mm in diameter (MORTON, 1996).

Subsequently, in order to improve access to the challenging area of the maxillary tuberosity, they designed osteotomes with modified anatomy. Composed of two parts, a double-folded shaft, and the tip. The shaft has a 30-degree bend from the longitudinal axis, followed by a second opposite bend of 10 degrees from the new axis. Thanks to these two folds, the tips are offset about 1.0 centimeters away from the main axis, presenting a final slope of 20 degrees. They would be of two different shapes, those of 1.8, 2.0, 2.9, 3.2 and 3.8 mm in diameter, with a conical shape and cutting end, and those of 3.4, 4.2 and 5.0 mm, with a cylindrical tip and a bevel end (NOCINI *et al.*, 2000).

Due to difficulties in insertion and correct positioning, due to the long length of the osteotomes of Summes, PASSADORE *et al.* (2003) presented a variation of the original concept with osteotomes that keep the same tip active, but with a short body and adapted to the use of a standard Branemark ratchet, facilitating its use in the posterior area of the maxilla (PASSADORE *et al*., 2003).

3.1.4 Meisinger's Controlled Bone Expansion Technique

The use of spiral expanders or Meisinger's controlled bone expansion technique is indicated because it facilitates the maintenance of proper positioning, faithful to the axis of insertion of the implant in the surgical bed, reducing the incidence of dehiscence or fenestration, allowing greater control during surgery and reducing the discomfort generated by the hammer used to strike the osteotome expander (ITINOCHE *et al.,* 2006).

Meisinger's controlled bone expansion technique uses an expansion "screw" and condensation drills with increasing diameters to condense and expand horizontally, gradually into the bone, enabling subsequent implant placement (SIDDIQUI & SOSOVICKA, 2006). Then, with the insertion of a larger diameter expander, the bone is pushed laterally (SCIPIONI *et al*., 1994), achieving a controlled and standardized horizontal bone dilation (NISHIOKA & KOJIMA, 2011). The expanders are inserted and tightened with a digital pressure, waiting approximately 20 to 30 seconds after each half turn (SIDDIQUI & SOSOVICKA, 2006), varying according to each type of bone. This expander technique has been shown to be a less invasive procedure than bone grafts, reducing trauma and allowing simultaneous placement of the implant (NISHIOKA & SOUZA, 2009), which should be slightly larger in diameter than the hole created by the expander (SCIPIONI *et al.,* 1994).

3.1.5 Osseodensification

Osseodensification is a technique that was introduced by Dr. Salah Huwais, a periodontist from Michigan, USA, in 2013, with the aim of performing the biomechanical preparation of the implant site. The procedure is characterized by low plastic deformation of the bone that is created by rotation and sliding contact using a densifying drill, designed to densify the bone with minimal heat elevation (HUWAIS, 2013).

The bone tissue, instead of being removed, is compacted and self-grafted forming a dense layer of tissue along the canal wall that will support the implant. Bone osseodensification is based on the condensation of bone through the use of drills with special characteristics that, operating in a counterclockwise direction (CCW), compact the bone debris in the canal walls. This method makes it possible to preserve bone mass, which would otherwise be removed in the perforation. One of the great advantages of this technique is the preservation of bone density, which in turn allows an increase in the contact surface between the implant and the bone, thus obtaining greater primary mechanical stability and accelerated healing (LAHENS *et al.*, 2016).

Until then, almost all other procedures performed involved bone removal to prepare the implant site. This concept preserves the bone crushed by the drill, aiming to plastically deform the bone. The bone densification technique ensures the preservation of bone volume through the compaction of cancellous bone by viscoelastic and plastic deformation and through bone autograft on the walls of the osteotomy. The bone is thus compacted and self-grafted around the preparation site and along the depth of the hole. In this way, the drill path creates an environment that increases primary stability through non-subtractive drilling. It should also be noted that in this technique, unlike conventional bone drilling, the bone displaced from the osteotomy orifice remains healthy, impacted on the lateral walls, especially in regions where the density is lower (HUWAIS, 2013; TRISI *et al.*, 2016; Huwais & Meyer, 2017).

Osseodensification through Bur Huwais S. Technology (Huwais & MEYER, 2015), sought to create a new process through appropriate instruments that would allow the maintenance of healthy bone during osteotomies, preserving the bone instead of removing it (HUWAIS & MEYER, 2015). This led to the concept of Osseodensification (OD) and the creation of Densah Bur drills. The blades are specially designed to precisely cut the bone clockwise and densify it counterclockwise (CCW). These drills have multiple conical geometry channels, being able to produce a faster evacuation rate with less heat production. The drills, when rotating counterclockwise, with the negative angle of the blades, compress the cut bone against the wall of the socket, creating osseodensification. In this way, the bone is preserved, preparing the canal for implant placement. These drills progressively increase the diameter of the canal throughout the surgical procedure, operating at 800 to 1500 rpm, cut and remove the bone when they run clockwise (CW), while preserving and condensing the bone counterclockwise (CCW). Densha Bur drill bits have segments with a negative tilt angle, which have a non-cutting action. They consist of sharp strands and a conical nail, thus expanding the osteotomy, penetrating deep into the bone and compacting the bone in the peripheral area. Then, instead of removing the bone fragments and debris, they send the bone fragments and debris to the implant bed. The pressure exerted on the walls of the socket, combined with the irrigation at the point of contact, creates a hydrodynamic effect, forming a compression wave, so that the bone is compressed laterally and simultaneously forcing the drill to advance. The lubricating effect of the cutter surface and the hydrodynamic compression are decisive for the densification process. Therefore, the design of the tip, together with that of the blades, facilitates compaction by performing an autograft (ISIS & MEYER, 2015).

3.2 ADVANTAGES AND CONTRAINDICATIONS OF BED PREPARATION

3.2.1 Advantages of ostheoexpansion

Regarding the advantages of osteoexpansion, alveolar expansion substantially improves the dimensions of the alveolar crest and the horizontal positioning of the implants. This procedure can also improve bone quality in type III and IV bones in the maxilla. Lateral bone condensation increases density and improves primary stability, considered one of the main reasons for successful osseointegration (LOPEZ *et al.*, 1996 and 1997).

3.2.2 Contraindication of bone expansion

Despite the promising results, the alveolar expansion technique has limitations. For success, there is a need for defined cortical and medullary walls, otherwise the technique will not allow the separation of the cortical walls (PARK, 2011).

3.2.3 Advantages of osseodensification

The RE helps the expansion of the crest while maintaining the integrity of the alveolar ridge, thus allowing implant placement in autogenous bone, also achieving adequate primary stability. The technique makes it possible to preserve the bone, shortening the waiting period for bone repair (HUWAIS & MEYER, 2015).

DO leads to an increase in primary stability due to different factors. During perforation in the bone bed, the extraction of bone tissue is practically non-existent, facilitating the compaction of the trabeculae of the medullary bone and the compaction of the bone particles, by autografting, along the lateral walls and apex of the osteotomized bed. Bone plasticity and the apex/alveolar crest movements with the drill, as well as a saline presence in the irrigation of the drill during drilling, allow the formation of a kind of pressure pump that imposes compaction, especially of the medullary bone. At implant placement, immediately after RE, the percentage of bone on the implant surface was indicated to be approximately three times higher than with standard drilling (PEREIRA *et al*., 2018).

Factors, such as the increase in the area of necrotic bone (PEREIRA *et al*., 2018), were indicated as possible determinants of the secondary stability of the implant, achieved after RE. LAHENS *et al*. (2016) analyzed peri-implant bone density and the biomechanical performance of implants in sheep animal models. Two months after the surgical intervention, after secondary stability had already been achieved, they showed an increase in BIC of 30% to 40% when compared to the group without RE (LAHENS *et al*., 2016). Although the temperatures reached by the DO technique, in the wall of the surgical socket, are higher than those reached by the traditional technique, the increase is not higher than 6 ºC, being insufficient to cause damage to the bone or even to condition the stability of the implant (PEREIRA *et al*., 2018). In addition, the increase in primary stability at values above 50 Ncm does not impair the achievement of secondary stability. This situation is due to the fact that high primary stability does not condition bone remodeling or the regenerative capacity of the tissue (GREENSTEIN & CAVALLARO, 2017).

3.2.4 Disadvantages and contraindications over osseodensification

The hypothesis of allying this technique in the presence of previous xenografts should be totally discarded, because it has only inorganic contents, its structural characteristic has a different functioning from the native bone tissue, in terms of viscoelasticity, becoming null. Another contraindication is based on the fact that bone ridges with predominantly cortical tissue have a vascularization index that does not allow tissue densification, and the effect can be remodeling, necrosis, and consequent loss of the desired surface (PIATTELLI *et al*., 1998; LOPEZ *et al*., 2017).

3.3 STATE-OF-THE-ART OSSEODENSIFICATION METHODOLOGY

During the surgical procedure, measurements should be taken with a bone caliper to confirm the width of the alveolar crest at the site where the implant will be placed. These measurements will be made at about 0.5 to 1 mm below the margin of the ridge. Measurements of the width of the alveolar ridge will be repeated in the second stage of surgery. This is followed by the surgical phase, where a horizontal incision is then made, extending to the entire edentulous area, plus a mesial and distal tooth, to be rehabilitated, ending with a discharge incision perpendicular to the axis of the crest. In the next step, the full-thickness mucoperiosteal flap is lifted with complete exposure of the alveolar bone, and the bone width is reconfirmed. Once the bone ridge is exposed, drilling begins with the pilot drill to reach the desired depth, at a drill speed of 800-1500 rpm, clockwise, with abundant irrigation. Once the drilling is finished, the osseodensification phase begins, starting with the Densah Bur drill, with a smaller diameter, at a counterclockwise drilling speed of 800-1500 rpm, under abundant irrigation. The progression of the drill is carried out with an interspersed apical movement, in successive pulses, until the stipulated depth is reached, sequentially increasing the Densah Burs drills to the established diameter. At the end of the osteotomy preparation, the diameter obtained should be 0.5 and 0.8 mm in less dense spinal cords, while in denser spinal cords, a diameter of 0.2 to 0.5 should be obtained, lower than the diameter of the implant to be installed (EL MAGHRABI, 2018). It should be noted that the technique does not clarify the classification of the bone type used in this diameter obtained.

When installing implants in the upper jaw, when the operator feels the tactile feedback of the drill, it is because the dense floor of the maxillary sinus has been reached, at this point he must stop and confirm the first vertical position of the drill with an X-ray. This is followed by the installation of the implant using the same motor, ending in the in-depth adjustment using a wrench with torque measurement. If the thickness of the cortical bone resulting from the RE is less than 1 mm, it is complemented with biomaterial (EL MAGHRABI, 2018).

3.3.1 Characteristic Advantages

Therefore, the RE technique has different advantages, such as: (A) Compaction: RE maintains most of the bone, due to bone condensation, resulting from an autograft, resulting in increased BIC; (B) Increased bone density: resulting from the increase in bone density through RE, allowing bone preservation, enabling autogenous grafting by compaction in the canal walls during osteotomy preparation, increasing peri-implant bone density and mechanical stability of the implant; (C) Preservation of medullary bone: accelerates healing, due to the maintenance of matrix bone, cells and other substances along the osteotomized surface; (D) Acceleration of healing: by preserving bone mass, the healing process becomes faster, due to the presence of bone matrix, cells and other substances that remain and are autografted along the osteotomized bed; (E) Expansion of the bone ridges: RE promotes this expansion by allowing the placement of implants with a larger diameter, avoiding fenestrations and dehiscence; (F) Residual tension: the movements of the drill in the DO (in and *out*) technique allow the pressurization of the irrigation to be exerted on the walls, facilitating bone plasticity and expansion; (G) Expansion of the bone ridge: maintaining alveolar integrity, it allows the implant to be placed next to the autologous bone, reducing the regenerative period (HUWAIS & MEYER, 2015; HUWAIS & MEYER, 2017; HUWAIS *et al.*, 2017; PEREIRA *et al.*, 2018).

4 CONCLUSION

Osseodensification suggested advantages over other bone densification techniques, such as ease of insertion of instruments and obtaining bone-implant contact with higher bone density. However, further studies are needed to enable longitudinal evaluations in order to verify the success of osseointegrated implants installed using staonsettals based on this technique.

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