ORIGINAL ARTICLE

INFLUENCE OF AN ADAPTED SURGICAL TECHNIQUE ON THE STABILITY OF DENTAL IMPLANTS: A STUDY IN BEAGLE DOGS

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OBJECTIVE: To study the osseointegration of dental implants placed in Beagle dogs using an adapted surgical technique and to compare it with conventional method by estimating implant stability by Resonance Frequency Analysis (RFA).

METHODOLOGY: Dental implants were placed bilaterally in the mandible of Beagle dogs using press-fit as well as undersized implant bed preparation technique. Assessment of primary stability was carried out 0 day, 2 weeks and 12 weeks after implantation using the RFA method, and Implant Stability Quotient (ISQ) values were recorded.

RESULTS: At the time of implant installation (day 0) the mean ISQ values were 64.41 ± 4.86 for the press-fit and 74.13 ± 4.47 for the implants inserted with the undersized preparation. The difference was found to be statistically significant ($p<0.01$). The ISQ values after 2 weeks and 12 weeks also showed similar trend however, these differences were not statistically significant ($p> 0.05$). No significant decreases were found in the ISQ value of the press-fit and undersized implants methods as compared to the day 0 ($p> 0.05$).

CONCLUSION: The results of this study showed that the undersized implant bed preparation may significantly improve the primary stability which may help in a better osseointegration. This method can be used in compromised bone to achieve better osseointegration.

KEY WORDS: dental implants, primary stability, Resonance frequency analysis, ISQ values, bone integration, surgical technique

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INTRODUCTION

Dental Implants have become the standard of care for replacing missing teeth mainly because of their high success rate and strength.[1-3] High implant success rates of the order of 78-100 % have been published, with more than 15 years of observation time.[4-6] Despite these high rates of success of dental implants for orofacial rehabilitation, a small but significant subset of patients continue to experience complications and implant failure.[7-8] The causes of failure have been reviewed without mandating a specific one.[7-8]

Studies reported that the most important goals in dental implant treatment is to achieve optimal implant osscointegration and the primary implant stability is a strong pre-requisite.[9] The primary implant stability depends on the factors such as implant geometry, surgical procedure, site preparation and bone quality of the recipient site.[10-11] In addition, implant stability is often difficult to attain in bone of low density.[12] Several modifications of surgical technique have been described to increase the primary stability of implant in bone of low density. For example,[13] Sennerby suggested that omission of tapping in low density bone to improve primary implant stability, while others have proposed bone condensation using osteotomes[14], using a final drill size smaller than recommended[15], or even placing a submerged implant with its collar in a supra-crestal position.[16-17]

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The primary stability, as obtained directly after implant installation is followed by a secondary stability phase, which is determined by the bone healing response. At the end of this secondary phase, the implant has to be completely osseointegrated, which has to be considered as a first guarantee for implant success.[18-19] Recently, few published clinical reports and animal studies have highlighted the advantages of under-sizing the implant bed for obtaining better stability and osseointegration, there is no convincing reports to support this method.[19-21]

Numerous methods have been anticipated to find out implant stability in medical practice. However, resonance frequency (RFA) has been found to be the most precise.[22] Meredith et al introduced RFA into implant dentistry in the 1990. Since then, it has become a extensively accepted and used technique.[23] The objective of the present study was to evaluate the osseointegration of dental implant placed using different surgical technique by assessing the resonance frequency Implant Stability Quotient (ISQ) at various time intervals during the healing process.

METHODOLOGY

Ethical approval:

Ethical approval was obtained from the Ethics Committee on Animal Research, College of Dentistry Research Center (CDRC), King Saud University, Riyadh, Saudi Arabia.

Animals

Ten adult Beagle dogs, weighing from 10 to 15 kg and aged between 9 to 12 months, were used in this study.

Extraction procedure

Teeth were extracted under general anesthesia under sterile conditions in an operating room. In order to sedate the animals, an Intramuscular (IM) injection of ketamine hydrochloride (5 mg/kg) and diazepam (1 mg/kg) was used, prior to the procedure. Povidone-iodine 10% and chlorhexidine solution in a ratio of 1:1 were used to rinse the oral cavities of the animals. Injection of lidocaine 2% with 1:100,000 epinephrine was used to anesthetize the area around the premolars of the animals. After complete anesthesia of the tissues, the lower second and third premolars were extracted. The technique consisted of separating roots with a high-speed bur in the presence of an intense water spray and the roots were removed with forceps. The flaps were closed with interrupted absorbable sutures using 4-0 bbs coated vicryl and without any further procedure the primary soft tissue closure was achieved [4].

Implant surgical procedure

After the healing period of 3 months, implant surgical procedures were performed under aseptic conditions by the same surgical team. Before the surgery, the dogs were sedated and local anesthesia was injected in the field to decrease bleeding and to induce post-operative analgesia. Subsequently, an incision was made at the bone crest and a full thickness mucoperiosteal flap was raised both on the buccal and on the lingual side of the alveolar ridge. Two implant sites per mandibular half were prepared using a low-speed drill, a graded series of burs and continuous saline irrigation. After that, a self-tapping implant with a diameter of 4.1 and length of 8.5mm (OSSTEM Implant System SS II, Seoul, Korea, http://www.osstem.com) was inserted in their designated positions [4] (Figure 1).

Two different surgical approaches were employed for the installation of the implant fixtures:

Group1. ***The press-fit technique:*** Surgical preparation of the implant sites was done with a consecutive series of drills up to a diameter of 3.8 mm. This included low speed drilling with sterile saline as coolant. Without any tapping, the implants were placed in the created implant bed.

Group2. ***An undersized preparation procedure:*** The final drill used in the procedure had a diameter of 3.3 mm. A pilot study had already indicated that a 4.1 mm implant could be placed in this kind of undersized preparation.

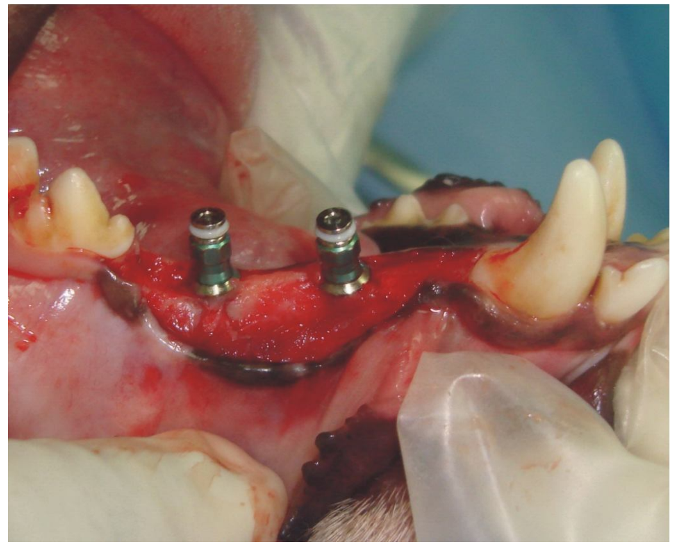

Figure 1. Implant surgical procedure

The entire implants were inserted manually. The Group 1 and group 2 implants were installed in one side of the mandible and in the contralateral side, respectively. Among various animals, the implant bed preparations in the left and right mandibular side, according to the Group 1 and 2 specifications were alternated. Further, the implants were placed in the lower margin of the "smooth" permucosal part in a flushed position with the crestal bone. Following the placement of implants, the flaps were closed with interrupted absorbable sutures using 4-0 bbs Coated Vicryl. Primary soft tissue closure was achieved without any additional procedure. An intramuscular broad spectrum antibiotic (Gentamycin 4 mg/kg body weight) was administered for 7 days. The dogs were maintained on soft diet for 2 weeks after the surgical procedure. None of the implants in this study were loaded; however, they penetrated the gingiva with their permucosal part.

Three months after the insertion of implants, the dogs were sacrificed to collect the jaw bone with the implants. Subsequent to premedication with a combination of Haloperidol® and Fentanyl®, the dogs were anesthetized using 30mg/kg Thiopental® followed by 0.5ml/kg Thromboliquine ® intravenous injection and a lethal dose of Thiopental®. The vascular system was perfused with physiologic saline, followed by 4% neutral formaldehyde as a fixative. After perfusion, the mandibles were dissected out immersed in 4% neutral formaldehyde.

Resonance frequency measurements

The resonance frequency measurements in this study were done using Osstell L-shaped transducers (Integration Diagnostics, Goteborg, Sweden). These transducers recorded all information as an implant stability quotient (ISQ), which is a function of bone-implant stiffness (N/μm) and marginal bone height

(Figure 2). The ISQ is a dimensionless quantity; larger ISQ values indicate increasing levels of interfacial bone-implant stiffness (and thereby higher integration stability). The resonance measurements were done immediately after insertion of the implants, 2 weeks after implant placement and after 3 months before retrieval of the jaw.

Figure 2. Resonance frequency measurements

Statistics

The statistical analyses were performed with GraphPad® Instat 3.05 software (GraphPad Software Inc, San Diego, CA, USA). An unpaired t-test was used to compare the ISQ values of undersized and press-fit implants Data are presented as mean ± SD (Standard deviation). Differences were considered significant at *p*-values less than 0.05.

RESULTS

Uneventful recoveries from surgery, healing of the extraction and implantation sites were found. At the end of the study, six press-fit and four undersized implants were found to be lost. No clinical signs of inflammation or adverse tissue reaction were seen around the rest of the implants

The implant stability was measured at the time of implant installation after 2 weeks and after 12 weeks (Figure 3, Table 1).

Days	ISQ Values	
	Press-Fit	Undersized
0 Day(mean±SD)	64.41±4.86	74.13±4.47**
2 weeks (mean±SD)	63.37±6.78	67.13±5.16
12 weeks (mean±SD)	67.24±6.27	69.13±5.67

Table 1: The resonance frequency (ISQ) values for the press-fit and undersized implants at three time intervals

Values are mean±SD. Groups compared: Press-fit quotient vs Undersized implants **P<0.01, "t" test.

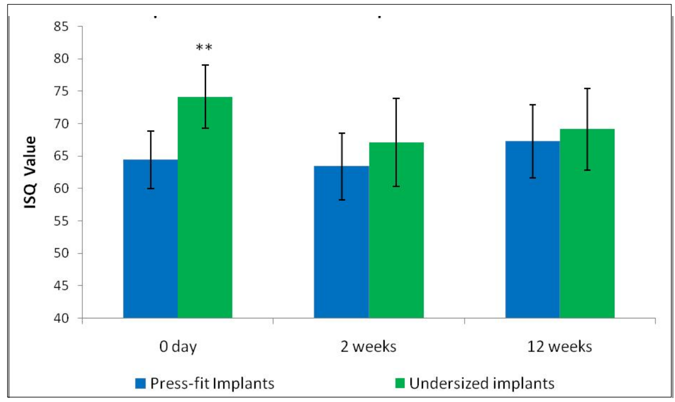

Figure 2 : The resonance frequency (ISQ) values (mean ± SD) for the press-fit and undersized implants at three time intervals

ISQ Implant Stability Quotient, Values are mean ± SD. Groups compared: Press-fit vs Undersized implants **P<0.01, "t" test.

The ISQ values were consistently higher in undersized implants compared to the implants inserted with press fit technique. At the time of implant installation the mean ISQ values were 64.41 ± 4.86 for the press-fit and74.13 ± 4.47 for the implants inserted with the undersized preparation. The difference was found to be statistically significant ($p<0.01$). The ISQ values after 2 weeks and 12 weeks also showed similar trend however, these differences were not statistically significant ($p>$ 0.05).

As compared to day 0 (64.41±4.86), insignificant results were observed at 2 weeks (63.37±6.78, $p>$ 0.05) and 12 weeks (67.27±6,27, $p>$ 0.05) time points in press-fit implants. The ISQ value of undersized implants also showed insignificant results at 2 weeks (67.13±5.16, $p>$ 0.05) and 12 weeks (69.13±5.67, $p>$ 0.05) as compared to the 0 day (74.13± 4.47).

DISCUSSION

Studies reported that implant success depends on patient characteristics, surgical technique and implant design. Factors such as bone quality and quantity determine the procedure and the type of implant according to their design and surface treatment.[13, 24-26] Implant stability is one of the crucial factors for a long-term success of osseointegration [27] and the bone density is a factor to take into account when predicting implant stability. [25] Several modifications of surgical technique have been described to increase the primary stability of implant in bone of low density. When conical implants are used the tapered design of the implant automatically condenses the bone. [26, 28-29] With parallel-walled implants, an adapted drilling technique results in higher success rates. [20] Therefore the diameter of the implant bed is modified depending on bone structure and morphology. In case of low supportive capacity of the jaw bone, the diameter of the canal drilled is reduced compared with the

standard protocol. This results in elevated bone condensation along the implant, and thus, higher insertion torque and primary stability.[30] Studies reported that the primary stability is obtained directly after implant installation, followed by a secondary stability phase, which is determined by the bone healing response. At the end of this secondary phase, the implant is completely osseointegrated, which has to be considered as a first guarantee for implant success. [18-19]

In the present study we compared the osscointegration of implants inserted with an undersized implant preparation and implants installed with the conventional procedure in a canine model. The stability of implants was measured by the resonance frequency analysis. Earlier studies reported several methods to determine implant stability in clinical practice. Among these, RFA has been found to be the most accurate. [22] Meredith et al introduced RFA into implant dentistry in the 1990. Since then, it has become a widely accepted and used technique. [23] The RFA values are represented by a quantitative unit called the ISQ on a scale from 1 to 100; an increased ISQ value indicates increased stability. [31] In our study we found that the ISQ values were consistently higher in undersized implants compared to the implants inserted with press fit technique. At the time of implant installation the mean ISQ value was significantly higher in undersized implants (74.13 ± 4.47) as compared to the press-fit implants (64.41 ± 4.86). The ISQ values after 2 weeks (63.37 ± 6.78 for press-fit implants; 67.13 ± 5.16 for undersized implants) and 12 weeks (67.24 ± 6.27 for press-fit implants; 69.13 ± 6.67 for undersized implants) also showed similar trend as baseline. However, these differences were not statistically significant. Studies reported that the acceptable stability range lies between 55-85 ISQ [32]. High initial stability (ISQ values ≥ 70) tends to not increase with time, even if the high mechanical stability will decrease to be replaced by a developed biological stability. Lower initial stability will normally increase with time due to the lower mechanical stability being enforced by the bone remodeling process. [32] If the initial ISQ value is high, a small drop in stability normally levels out with time. A significant decrease in ISQ indicates a potential problem and should be considered an early caution. [33] In the present study no significant decreases were found in the ISQ value of press-fit and undersized implants methods as compared to the day 0 ($p > 0.05$). Furthermore, several authors have studied the effect of primary stability on the development of stability during healing. [34] The recent investigation by Karl et al [35] assumed a general increase in stability during healing as a common phenomenon. This appears to be a confused view of the authors. Conversely, some authors have indicated that changes in stability during healing were mainly dependent on the initial stability level of an implant.[36] However; Balshi et al[37] concluded that implants with high primary stability lose part of their stability during healing, while implants with low primary stability have a tendency to increase their stability.

Research shows that the better primary stability of implants can be achieved by modifying the surgical technique. [19, 38] This technique may be appropriate in bone of lower density. Relative motion of the implant during the early stages of bone healing can adversely affect the osseointegration. [39-40] The ideal implant design should mechanically interlock with the bone at the macro level to provide stabilization. Thread engagement, friction fit or a combination of both are the methods used for root form implants to achieve initial stabilization. [41-42] When bone quality is compromised the undersizing of the implant bed can be used to achieve a better stability and thereby preventing micromovement. The observations of the present study further emphasize the possible advantage of bone condensation technique practiced by osteotome technique to achieve osseointegration in compromised bone quality. [43-45] Mechanical stimuli are said to accelerate the formation of trabecular bone. [46-48] The present study showed better stability with the undersized implants which can be related to a better healing of bone to implant surface. An increased new bone formation of compressed trabecular bone compared to native trabecular bone has been proven in previous animal experiments. [49] Compression of the trabecular bone displaces the marrow spaces. Although the bone density is increased, the blood supply is not disturbed severely. Because of its visco-elasticity, trabecular bone maintains the ability to expand to twice its volume after a 20 MPa compression. Moreover, the osteocytes of the trabecular bone remain intact when the force of compression does not exceed 10-20 MPa. [48]

Earlier studies suggested that the main concerns to osseointegration is the heat generation during the preparation of the implant site with drills and condensation of the implant bed by the additional torque required for installing undersized implants. [50-52] However, the present study observations showed no unfavorable effect on the adjacent bone. This is agreement with the previous studies. [52-54]

In conclusion the results of this study showed that both undersized and press-fit implants showed good osseointegration reflected in the ISQ values. However, the osseointegration of implants placed with the undersized technique showed relatively higher ISQ values compared to the conventionally placed implants. It can be assumed that the undersized technique may be used for placing implants with lower bone qualities. Further studies may be necessary to substantiate this observation.

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