Impact of Bone Quality and Implant Type on the Primary Stability: An Experimental Study Using Bovine Bone

ARTICLE *in* JOURNAL OF ORAL IMPLANTOLOGY · MAY 2013

Impact Factor: 0.98 · DOI: 10.1563/AAID-JOI-D-11-00156 · Source: PubMed

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Journal of Oral Implantology

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--Manuscript Draft--

Manuscript Number:	AAID-JOI-D-11-00156R3
Full Title:	Impact of bone quality and implant type on the primary stability: an experimental study using bovine bone.
Short Title:	Bone quality on implant stability
Article Type:	Research
Keywords:	implants; removal torque; Primary Stability; osseointegration; resonance frequency analysis
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Abstract:	The purpose of this in vitro study was to compare the primary stability and removal torque of bone level and tissue level implants in different bone quality. Fifteen tissue level and bone level implants (3.3x10mm and 4.1x10mm) were used for assessing the stability in type II and type IV bone. Forty bovine rib blocks were used in this study. The primary stability of the implant was measured by the resonance frequency using an Osstel ® device. The removal torque values (RTV) of the implants was assessed using a Digital torque gauge instrument. The Implant Stability Quotient (ISQ) values and the RTV showed a marginally higher stability with bone level implants as compared to tissue level implants. However, these differences were not statistically significant in both type of bone used (P>0.05). On the other hand, compared to type IV, type II bone showed significant differences in the ISQ (P<0.01) and RTV (P<0.001) of bone level and tissue level implants. The study concluded that bone quality is an important factor in establishing primary stability than the implant dimension. Bone level and tissue level implants of same dimensions can be selected based on the esthetic demands since they showed similar mechanical properties.

Impact of one quality and implant type on the primary stability: an experimental study using bovine bone.

Abstract

The purpose of this in vitro study was to compare the primary stability and removal torque of bone level and tissue level implants in different bone quality. Fifteen tissue level and bone level implants (3.3x10mm and 4.1x10mm) were used for assessing the stability in type II and type IV bone. Forty bovine rib blocks were used in this study. The primary stability of the implant was measured by the resonance frequency using an Osstel ® device. The removal torque values (RTV) of the implants was assessed using a Digital torque gauge instrument. The Implant Stability Quotient (ISQ) values and the RTV showed a marginally higher stability with bone level implants as compared to tissue level implants. However, these differences were not statistically significant in both type of bone used (P>0.05). On the other hand, compared to type IV, type II bone showed significant differences in the ISQ (P<0.01) and RTV (P<0.001) of bone level and tissue level implants. The study concluded that bone quality is an important factor in establishing primary stability than the implant dimension. Bone level and tissue level implants of same dimensions can be selected based on the esthetic demands since they showed similar mechanical properties.

Key Words: *implants; removal torque; primary stability; osseointegration; resonance frequency analysis.*

Introduction

Successful osseointegration has an important influence on the long term success of dental implant restorations. While primary implant stability and osseointegration can be predictably achieved in dense bone, it is often challenging to achieve the same in areas with poor bone quality.[1] Primary stability lowers the level of implant micromotion, which in turn allows uninhibited healing and osseointegration.[2] Friberg et al [3] reported an implant failure rate of 32% for those implants that showed inadequate initial stability.

Studies have demonstrated that initial implant stability is influenced by factors such as the length and diameter of the implant, the implant design, the micro-morphology of the implant surface, the insertion technique, and the congruity between the implant and the surrounding bone.[4-7] Further important determinants are the quality and quantity of the bone. Low density bone implant sites have been pointed out as the greatest potential risk factor for implant loss when working with standard bone drilling protocols.[8, 9] Clinical study with consecutively placed implants that were immediately loaded showed a higher failure rate in low density bone, reinforcing that primary stability is a major determinant in the success of immediately loaded implants.[10, 11]

The success of implant depends on the bone quality and the healing at the at the implant-bone interface. The structural and material properties of bone such as mineral density and mineral maturity are important contributors to bone strength [12, 13]. Even though majority of literature defines the bone quality in terms of bone density, other biological factors such as bone metabolism, cell turnover, mineralization, maturation, intercellular matrix, and vascularity are also factors that influence the osseointegration.[11, 12] The stiffness of the bone around the implant increases during the process of osseointegration, and the interlocks between bones and implant surface prevents micro-motion and formation of fibrous scar tissue when the implant is loaded properly.[14, 15] Basically, the stability of implantation is largely associated with osseointegration and peri-implant bone remodeling during healing process .

Bone level implants were introduced by the International Team for Implantology (ITI) to minimize crestal bone loss and to improve the esthetic predictability of implant-based restorations. The biomechanical properties of these implants are not thoroughly explored. Also the claim that these implants have lesser crestal bone loss compared to tissue level implants is also controversial. The reason for this controversy is that implant abutment junction (microgap) is closer to the bone which may results in more bone loss. However, in terms of esthetic point of view bone level implants are superior to tissue level implants.[16]

Number methods are used to assess the primary stability of the dental implant.[17] Among these resonance frequency analysis has been revealed and widely used as the most successful method to assess primary stability because of its easiness, accuracy, and non-invasiveness.[1, 18] The implant-bone interface is measured based by resonance frequency (RF) which is the reaction to oscillations exerted to the implant, and is expressed as implant stability quotient (ISQ).[19] On the other hand mechanical test such as insertion torque and values of push-out test showed positive correlation to the primary stability.[20, 21] Hence noninvasive measurement methods have also been introduced for the diagnosis and prediction of immediate and the long-term implant stability. Studies have shown that the measurement of removal torque strength was a useful indirect biomechanical method to evaluate the bone and implant interface.[22, 23] The purpose of this in vitro study was to compare the primary stability and removal torque measurements of bone level and tissue level implants in different bone quality.

Materials and methods

Fresh bovine ribs procured from the butcher shop were used for the study. They were cut into 6 cm long pieces and a total of 40 bovine rib blocks were prepared. The cortical bone was removed until it was about 1 mm thick in order to make it mimic to type II bone.[24] The other 20 blocks had all cortical bone removed and exposed the trabecular bone to make it similar to type IV bone (Fig 1). 20 tissue level (standard plus) and 20 bone level implants with two different dimensions (3.3 x10 and 4.1x10) were installed in each rib blocks (Fig 2).

Resonance frequency (RF)

After installation, the ISQ was measured by using resonance frequency analyzer (Osstell, Osstell AB, Goteborg, Sweden). The osteotomy sites were prepared according to the manufacturer’s guidelines. After implant insertion, the magnetic wireless RF analyzer was used for direct measurement of the endosseous implant stability. The RF analysis technique analyzes the RF range (110–10000 Hz) of a smartpeg® which can be attached to the implant. The probe of wireless RF analyzer, Osstell Mentor™ was held perpendicular to the implant as indicated by the manufacturer (Fig 3).

Removal torque values (RTV)

The RTV of each implant was measured using a digital torque MGT 50® digital torque gauge instrument (MARK-10 Corp., New York). A controlled, gradually increasing rotational force (displacement 0.5 mm min-1) was applied to the implant until implant loosening (Fig 4). The peak force measured at implant loosening was scored as the torque-out value.[25]

Statistical Analysis

The statistical analysis was performed with GraphPad® Instat 3.05 software (GraphPad Software Inc, San Diego, CA, USA) using analysis of variance (ANOVA). Tukey-Kramer multiple comparisons test was used to compare the ISQ values and RTV of the two types of implants with two different dimensions. p-values <0.05 were assumed to be statistically significant.

Results

The mean values and standard deviations of resonance frequency measurements are shown in Figure 5. Bone level implants showed ISQ values of 67.35 ± 5.21 and 71.65 ± 5.85 respectively for the 3.3 and 4.1 diameter implants. These values were higher than tissue level implants of the same dimension. Similar results were also found in type IV bone (Fig 5). Compared to type IV bone, the primary stability of type II bone showed significantly higher values (P<0.01) for the 3.3 and 4.1 diameter implants.

The removal torque values are depicted in Figure 6. The removal torque measurements showed no significant differences between bone level and tissue level implants with the two different dimensions of the implants used (Fig 6). However, significantly lower removal torque values were observed in type IV bone as compared to the type II bone (P<0.001).

Discussion

Implant stability is a prerequisite for the long-term clinical success of osseointegrated implants.[26, 27] The stability of implants can be successfully assessed by the Osstel device which quantifies the RF. Resonance frequency is a noninvasive, objective method to evaluate implant stability and it has been validated through *in vitro* and *in vivo* studies.[19, 28] The technique is based on the measurement of the RF of a small piezoelectric transducer attached to an implant or abutment.[19, 29]

It is well known that primary stability of implants depends on surgical techniques used, bone density, and implant design.[30-32] Maintenance of low implant micro-movement, especially in the early healing phase is important to promote direct bone in growth to implant surface.[33] Earlier studies have shown a linear relationship between the exposed implant height and the corresponding ISQ values. [21, 34] Sim and Lang [35] reported a correlation between the ISQ values and the bone structure and implant length. On the other hand O'Sullivan et al [36] failed to report any correlation between the implant primary stability and the shape of the implant. In the present study a comparison was done between bone level implants and tissue level implants with similar dimensions. Bone level implants showed slightly higher but insignificant ISQ and removal torque values as compared to the tissue level implants.

However, when the primary stability implants were compared in different bone quality, a statistically higher ISQ values were observed for implants inserted in Type II bone with 1 mm cortical bone. This observation is in agreement with observation of Akca et al [37] who reported that bone quality had more influence than implant shape. Elias et al [15] concluded that implant design, surgical technique and substrate type are the major components influencing the primary stability.

Bovine rib was used in this study and is classified as type II bone in other studies since contains thick compact bone and dense trabecular bone.[38] In order to mimic the type IV bone the entire cortical bone is removed. The lower ISQ values and removal torque observed in this experiment indicates that the bone quality is an important determinant in the early implant stability. There were significant correlations between bone density and removal torque values which is in agreement with earlier studies.[39, 40]

To evaluate the initial bone quality and degree of osseointegration, various methods have been proposed [41], including histology and histomorphometry [42-45,] removal torque analysis,[46-48] pull- and push-through tests [49] and X-ray examination [30]. RFA has been used to study the factors, including surgical technique, loading protocol, and implant design that govern implant stability. The implant stability can also vary with a change in osseous remodeling and percentage of implant bone interface contact. [50] The major drawback of the RFA analysis is that it can only reflect the mechanical property of the bone -implant interfacial layer by assessing the changes of stiffness during osseointegration process. [29, 41, 51] Even though it is an excellent nondestructive method its clinical application is limited to establish the implant stability and the prognostic criteria for long-term implant success.[52, 53]

Within the limitations of the study, it can be assumed that bone quality is an important factor in establishing primary stability than the implant dimension from the biomechanical point. The main limitation of the present study is that the mechanical characteristics of the primary stability of an implant were considered in an *in vitro setup* using bovine bone. Further *in vivo* studies are required to understand the actual clinical situation in which many biological factors influence the primary stability of implants. Moreover secondary stability tests, finite element studies (FEA) and histomorphometric studies are necessary to substantiate the present observations.[54] The priority for selecting either a bone level or a tissue level implant of same dimension should be based on the esthetic demands since they showed similar mechanical properties.

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Legends to figures

Figure - 1. The bovine rib showing type II and type IV bone .

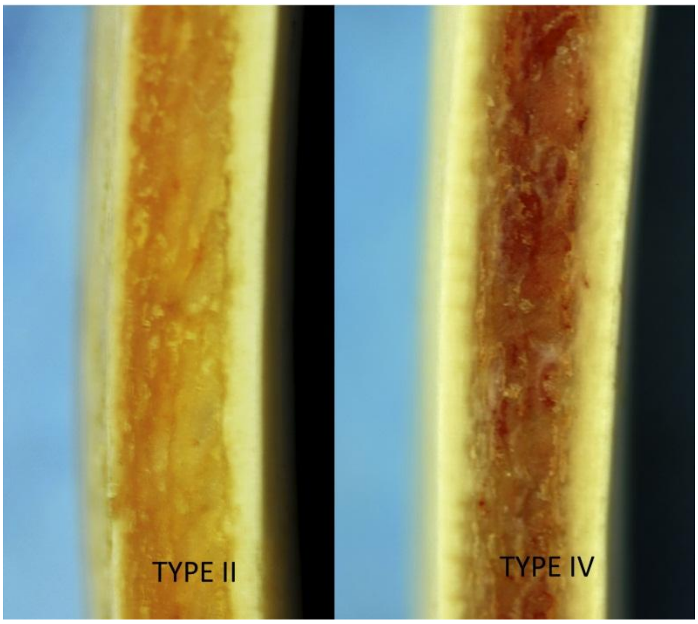

Figure - 2. Illustration showing the positioning of tissue level and bone level implants.

Figure - 3. The implant in position with the SmartPeg™ and the tip of the Osstel Mentor resonance frequency analyser.

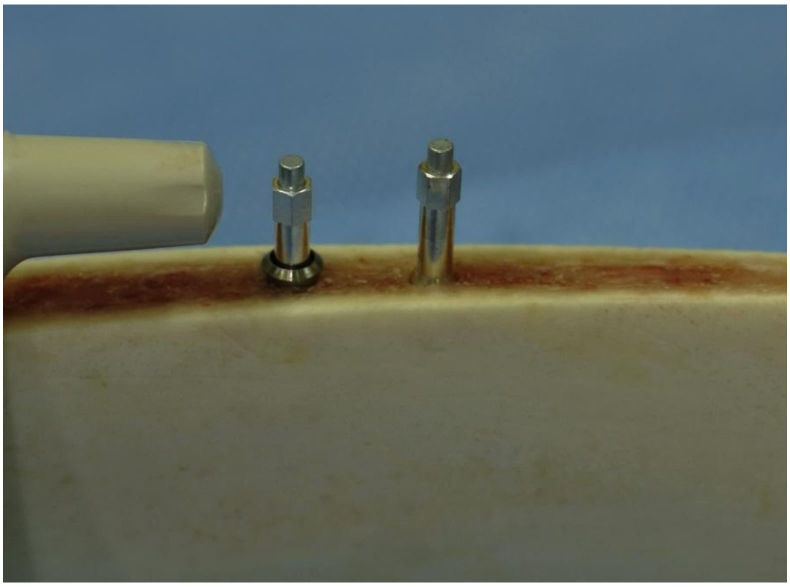

Figure - 4. The positioning of the digital torque gauge.

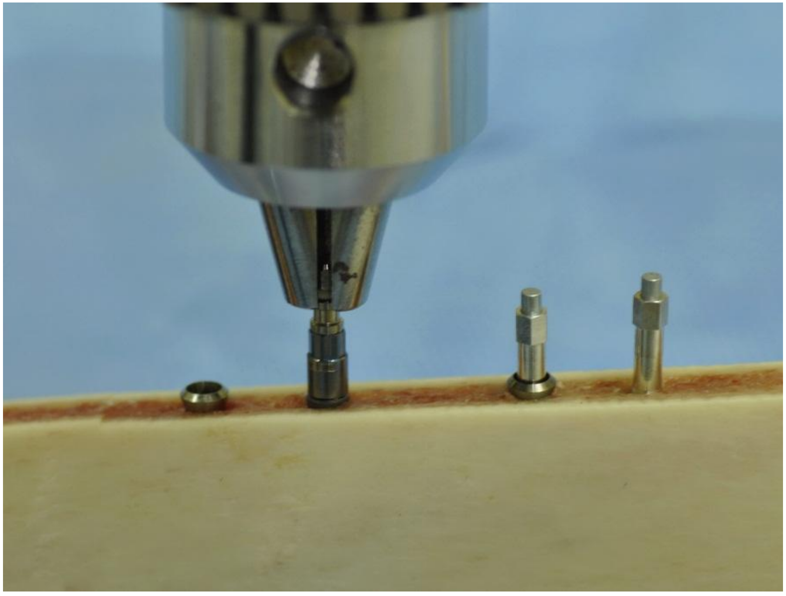

Figure-5. The RF values (ISQ) of bone level and tissue level implants in Type II and type IV bone.

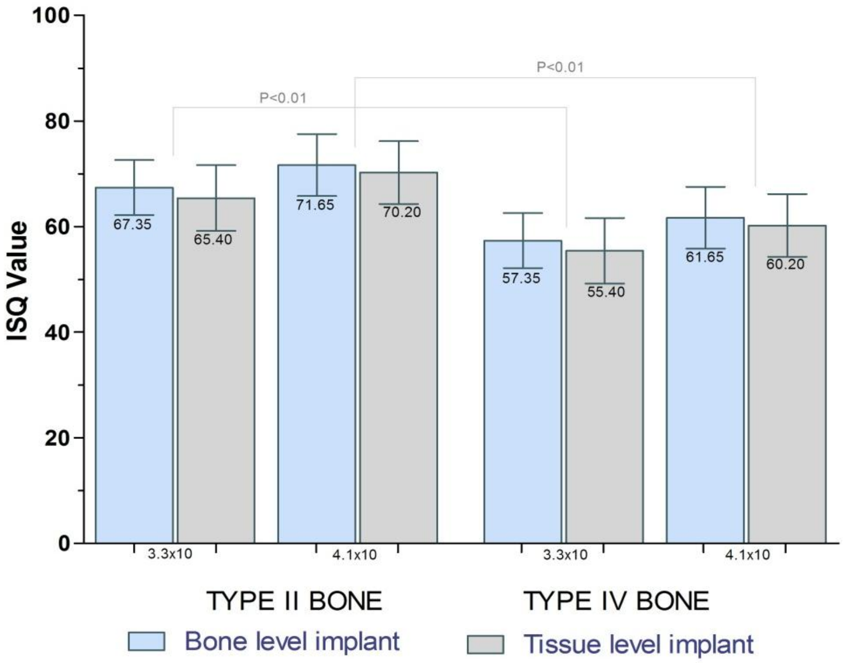

Figure-6. The removal torque values (RTV) of bone level and tissue level implants in Type II and type IV bone.