

Influence of different implant placement techniques to improve primary implant stability in low-density bone: A systematic review

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Abstract

Aim: The aim of this study is to assess the influence of different implant placement techniques to improve primary implant stability (PIS) in the low-density bone.

Materials and Methods: Citations published in English and those available in full text were searched from electronic databases (PubMed and Google Scholar) from the year 2000–2017 by which 75 manuscripts were revealed. After applying inclusion and exclusion criteria, seven were selected for the present review. The whole process was conducted by the following preferred reporting items for systematic reviews and meta-analyses guidelines.

Results: The measurement of primary stability showed significant correlations with different bone densities and with implant outcome; however, these two parameters have not been investigated at the same time frequently. Of the seven manuscripts, three discussed standard drilling protocol, two used undersized drilling, one used guided drilling, and one compared standard drilling with undersized drilling. Several intraoperative methods of jaw bone-density assessment were reported, and resonance frequency analysis, periotest, and insertion torque values were used to quantify PIS.

Conclusion: The use of undersized drilling has proven advantageous for increasing initial implant stability in the low-density bone. Although the PIS may be lower, the secondary implant stability is found to be correlated to acceptable values.

Keywords: Bone density, guided drilling, osseointegration, primary implant stability

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INTRODUCTION

Primary implant stability (PIS) is a critical factor that determines the long-term success of dental implants. PIS is defined as the absence of mobility in the bone bed after

the implant has been placed.^[1] According to the Glossary of Prosthodontic Terms, Ninth Edition, PIS is a contributing factor to the mechanical stabilization of a dental implant during the healing phase.^[2]

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An implant exhibiting minimum micromotion after surgical placement and during the initial healing phase has greater longevity with reduced bone loss. To achieve predictable success with dental implants, PIS is required. Low values of PIS may increase the risk of early failure to osseointegrate, while good initial stability provides better conditions for success since it allows for smaller micromotions between the implant and the bone.^[3]

The quality of bone plays a major role in the initial bone-to-implant contact. Trabecular bone is less dense compared with the cortical bone. In certain areas of the jaws (particularly the maxillary posterior region) and in certain condition (e.g., osteoporosis), the bone may have trabecular morphology.^[4] This, in turn, will affect the degree of firmness with which the implant has been placed, thus influencing PIS. Other factors that influence PIS are length and diameter of the implant, implant design, micromorphology of the implant surface, insertion technique, and congruity between the implant and the surrounding bone.^[5]

Implant stability can be further divided into primary and secondary stability. Primary stability is mostly derived from mechanical engagement with cortical bone and the absence of mobility in the bone bed on the insertion of the implant and depends on the quantity and quality of bone, surgical technique, and implant design. Secondary stability depends on bone formation and remodeling at the implant-to-bone interface and is influenced by the implant surface and the wound healing time. The former is a requirement for successful secondary stability; the latter dictates the time to functional loading.

Several classifications for bone density have been recommended. According to Misch^[6] in 1988, bone quality can be classified into four types (D1–D4) based on macroscopic and trabecular characteristics. D4 bone is finely trabecular and often lacks cortical bone. This type of bone is commonly found in the posterior maxilla, shows a Hounsfield unit (HU) reading between 150 and 350 units, exhibits the lowest implant-to-bone contact, and has the maximum failure rate of the four types of bone. Implant failure rates range from approximately 3% after insertion of implants into bone Types 1, 2, or 3, to approximately 35% after insertion into bone Type 4.^[7] It has been observed that PIS is lower in Type 4 bone than in types 1-3.^[8] Various techniques have been used to improve the PIS in type 4 bone.

Friberg *et al.* recommended the use of undersized drilling to optimize implant stability in less dense bone.^[9] Summers,

(1994) proposed the use of a bone condensing technique using condensers after a pilot drill to displace the bone at the periphery of the cavity.^[10] Fully guided surgery has been suggested, using templates to translate the precise positioning into clinical reality and to allow for exact, guided preparation of the implant site. This affects the regions with poor bone qualities and may lead to smaller micromotions between the implant and the bone. Other methods use cylindrical implants instead of tapered implants and the additional incorporation of surface treatments. The bone quality of the receptor site influences the primary stability of implants, and bone density. Hence, the present systematic review was conducted to evaluate and compare different techniques that are presently in use to enhance the primary stability of implants placed in regions of poor bone mineral density. In addition, a critical review of methods of measuring PIS has also been undertaken.

MATERIALS AND METHODS

Search strategy

A MEDLINE (PubMed), Google Scholar, and Cochrane library search were conducted to identify all articles that investigated PIS immediately after implant placement in regions of compromised bone density from January 2000 to July 31, 2017. The search strategy included appropriate changes in the key words following the syntax rules of each database. Since bone density has been also referred to as bone quality, the following search parameters were used: “assessment of bone quality in human jaw bone,” “surgical protocol,” “adapted surgical protocol,” “insertion torque (IT),” “resonance frequency analysis,” and “jaw bone quality.” This systematic review was performed in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement.

The inclusion criteria were observational clinical studies on patients who had dental implants placed in regions with poor bone mineral density, including conventional procedure and any adapted protocol. The exclusion criteria were unspecified bone mineral density, lack of comment on bone quality, nonhuman studies, and studies in which PIS had not been objectively defined.

Of the 75 retrieved articles, those reporting of comparisons of PIS among cases with poor bone mineral density were selected. The selected articles discussed varying protocols for surgical placement. After the review of titles and abstracts, 20 articles were chosen for further study. Finally, seven articles were shortlisted for the final review, as the rest did not meet the inclusion criteria.

Figure 1 provides a PRISMA flowchart of the identification and selection of the study. A summary of the selected articles is presented in Table 1.

RESULTS AND DISCUSSION

Clinical strategies to increase the implant success rates in areas of reduced bone quality include the use of longer or wider-diameter implants, the use of implants with roughened surfaces, undersizing the osteotomy followed by the placement of a self-tapping implant that is 1–2 mm wider than the initial preparation, and the use of osteocompressive techniques.^[16] These techniques are intended to increase bone-to-implant contact.

The osteotome technique is mainly designed for gradual densification of the osteotomy in both the axial and lateral direction,^[17] which improves bone quality. The molding of the bone around the site of implant placement is carried out by the sequential compaction of the bone.^[18] The densification of bone allows for greater physical interlocking between bone and the implant which results in higher degrees of primary stability.

The placement of implants in undersized sockets to increase primary stability is controversial. Compressive forces are set up along the implant-to-bone interface, which leads to a mismatch between the hole and the implant diameter; forces are then evenly distributed along the length

of the implant-to-bone interface.^[19] This technique also allows for remodeling around the implant to increase the bone-to-implant contact, which also increases secondary stability.^[14]

The converse view states that, when implants were placed with excessive torque (compressive forces), a greater amount of resorption was observed due to the creation of microfractures.^[20,21] In addition, an *in vitro* study by Jimbo *et al.*^[22] has shown that loss in biomechanical implant stability was noted due to interfacial remodeling or necrotic changes of the surrounding bone.

Möhlhenrich *et al.* have compared different surgical techniques for implant site preparation in different artificial bone densities (decreasing density D2, D3, and D4). On the evaluation of conventional free-hand drilling, fully guided procedures, and condensing, the authors found that condensing resulted in significantly better PIS compared with conventional and guided procedures when using short implants. In low-density bone, wide-diameter and longer implants improved stability.^[21]

In another study, Falisi *et al.*^[23] evaluated five different implant placement techniques (piezosurgery, conventional, under-preparation, bone compaction, and osteodistraction) in 10 *in vitro* samples and found that all methods were interchangeable; none had a major advantage over the other. Xing conducted a study on 16 patients with poor

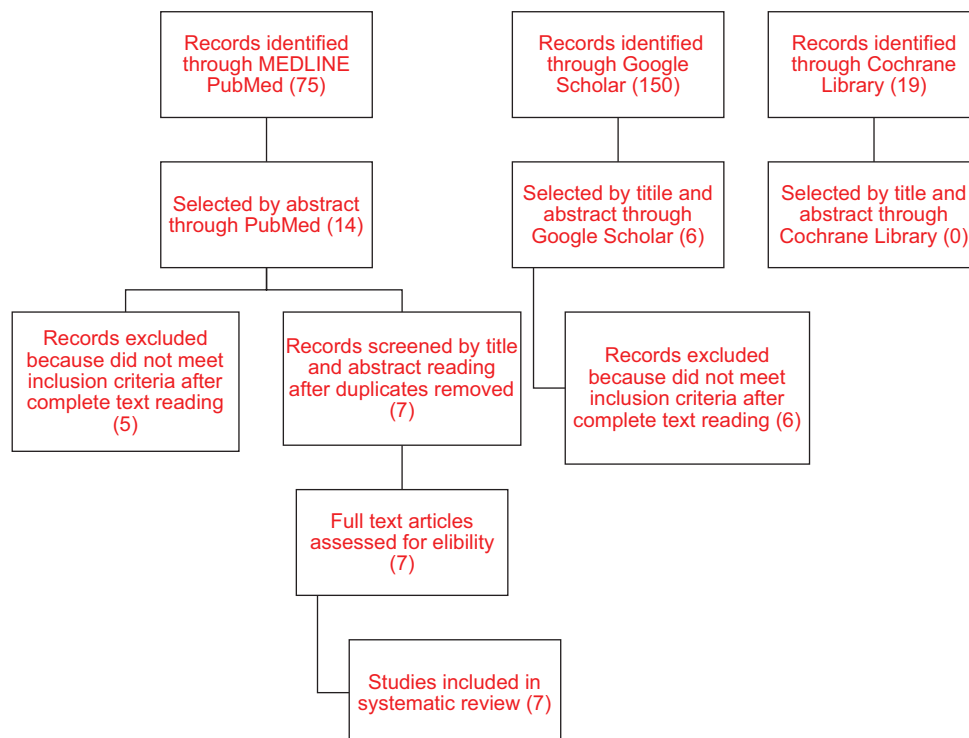


Figure 1: Selection of articles

Table 1: Studies on primary implant stability

Author and year	Implant and manufacturer	Implant size	Implant number	Region	Bone type	Technique of evaluation of stability	Result of evaluation	Insertion technique	Other findings
Pozzi <i>et al.</i> , 2012 ^[11]	57 nobel speedy replace implants and 24 nobel speedy groovy (PS1)	Not specified	29 axial and 42 straight	Atrophied maxillary posterior	Not specified	IT	40-50 Ncm	Underprepared osteotomy	
Alghamdi <i>et al.</i> , 2011 ^[5]	Straumann (standard plus) (PS2)	4.1 mm × 12 mm	26	Posterior maxilla and mandible	Lekholm and Zarb 3 and 4 according to radiographic assessment and drilling resistance	IT and RFA	IT - 35.19±4.79 ISQ - 68.58±4.81	Undersized drilling	Comparison of standard osteotomy in normal bone and undersized osteotomy in bone with low bone mineral density
Herekar <i>et al.</i> , 2014 ^[12]	Nobel replace select (Nobel Biocare) and GSIII/TSIII (Osstem)	Not specified	20	Not specified	D4	RFA	60±4.15	Standard drilling protocol	Comparison of primary and secondary ISQ of the different types of bone
Alsaadi <i>et al.</i> , 2007 ^[8]	Mark III TiUnitet implants (Branemark systems, Nobel Biocare, (PS3))	Not specified	47	Not specified	Lekholm and Zarb 4	Periotest	3.28 - crestal, 5.49 - middle, 8.38 - Apical	Standard drilling protocol	
Makary <i>et al.</i> , 2011 ^[13]	Tapered Screw-Vent MTX, Zimmer Dental	4.1 or 4.7 mm diameter	9		D4	IT	40.22 Ncm	Standard drilling protocol	Trephine drill used initially to obtain biopsy to determine the bone type
Anitua <i>et al.</i> , 2015 ^[14]	BTI implants (BTI, Vitoria, Spain)	8.5 mm-long			Lekholm and Zarb 4	IT	34.84±2.38 Ncm	Socket under-preparation by 1 mm	
O'Sullivan 2004 ^[15]	Branemark Standard implants (Nobel Biocare AB, Gothenburg, Sweden), Branemark SystemR Mk IV implant (Nobel Biocare AB)	Not specified	9 (4 Standard implant and 5 Mk IV implant)	Not specified	Lekholm and Zarb 4	IT RFA	14.0 and 12.3 Ncm respectively 5.6 and 5.86 KHz	IT increases due to inherent cutting property of implant	Inducing greater stresses in cortical bone

IT: Insertion torque, ISQ: Implant stability quotient, RFA: Resonance frequency analysis

bone quality and found that there was no statistically significant difference between a conventional drilling protocol and osteotome technique using IT and resonance frequency analysis (RFA) over varying time intervals.^[16]

The surgical protocol followed in the study conducted by Anitua *et al.*^[14] adapted the implant socket preparation so that sufficient primary stability to permit osseointegration of the dental implant could be established. The underpreparation of the socket was increased according to the decrease in the quality of the hosting bone, reaching a maximum value of 1.2 mm. In the D4 type of bone, an IT of 34.84 ± 2.38 Ncm was obtained, but an adequate IT (≥30 Ncm) was not obtainable in bone with a density <400 HU.

O'Sullivan *et al.*^[15] used two different types of implants and proposed varied implant placement protocols to assess implant stability. Standard Brånemark System® implants (Nobel Biocare AB, Gothenburg, Sweden) were

inserted with a technique designed to enhance primary stability.

Cavallaro *et al.* and Engelke *et al.* concluded that changes in the drilling protocol are necessary to improve PIS for different bone densities.^[24,25] This includes an undersized osteotomy and to submerge the implant to allow for osseointegration.

The value of PIS allows a comparison of the PIS at various time intervals and in different bone types. The commonly used methods are measurement of the IT, RFA, and Periotest. High values of IT, RFA, percussion energy response, or removal torque indicate good stability, while lower values indicate less than optimum stability.

The force used to insert a dental implant is called IT.^[26] It can be assessed by electronic devices incorporated with the physiodispenser or with a torque gauge incorporated with manual ratchets.^[27] A disadvantage of this method is

that IT varies depending on the cutting properties of the implant and the presence of fluid at the osteotomy site. However, the method does provide some information about the energy used when placing the implant. Its main disadvantage is that, like the surgeon's perception, IT measurements can only be assessed at the time of implant placement; torque measurements cannot be repeated during follow-up appointments and hence, longitudinal data cannot be obtained.

The RFA technique is fundamentally a bending test in which a minute tilting force, on the bone-implant system, is applied by stimulating a transducer. It is a noninvasive diagnostic technique that measures implant stability at various points in time using vibration and principles of analysis of structural form. The advantage of RFA is that it can be evaluated at various time intervals.

Choosing an appropriate stability measuring tool depending on local anatomic factors enables a more accurate estimation and better prediction of implant success. Studies have shown that RFA is the only method that can detect significantly different effects of various factors on primary stability. Further, it has been reported that RFA may be difficult to interpret in the evaluation of implant stability in softer bone density. RFA and IT measure the implant stability at different levels of the bone-implant interface.^[16] RFA is dependent on the cortical thickness of the bone, while IT quantifies trabecular bone quality.^[16] Thus, RFA may show varying values in low-density bone depending on cortical bone density.

Of the articles included in the study, three studies used implants with anodized surfaces (thickened layer of titanium dioxide coated on the surface),^[8,11,12] study by O'Sullivan *et al.* used sandblasted and acid-etched implants,^[15] study by Alghamdi *et al.* used sandblasted implants,^[5] study by Anitua *et al.* used implants chemically treated with calcium ions,^[14] and study by Makary *et al.* used implants with machined surfaces.^[13] The studies using implants with different surface treatments showed high PIS. In contrast, the study by O'Sullivan *et al.*,^[15] in which Standard Nobel Biocare implants were used, exhibited low PIS. This implies that to attain high PIS in low-density bone, it is always recommended to use implants with some surface treatment, as opposed to machined implants.

In order to improve primary stability, the use of implants with a thread design is preferred. Of the articles included in the current review, all the implants had a threaded design. The Nobel Speedy implants are designed to provide increased primary stability since they allow

for underpreparation.^[11] The Straumann Standard Plus implants provide a cutting surface.^[5] On the other hand, the Brånemark System Mk III implants are indicated for medium to hard bone and are provided with three cutting chambers. Thus, in poor-quality bone, an implant type that allows for osseodensification by the compression of the bone is preferred. Straumann Standard Plus implants were used by Alghamdi *et al.*^[5] in an under-prepared socket by placing a 4.1-mm diameter implant in a 2.8-mm osteotomy site to achieve improved IT.

In cases of low bone mineral density, the initial evaluation must include both IT and RFA since the RFA has been found difficult to interpret. The IT will give an initial assessment of PIS while further evaluation can be conducted by RFA to assess secondary implant stability and in turn, evaluate time to implant loading.

CONCLUSION

The use of undersized drilling has proven advantageous for increasing initial implant stability in the low-density bone. Although the primary implant stability may be lower, the secondary implant stability is found to be correlated to acceptable values.

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Conflicts of interest

There are no conflicts of interest.

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