Dental Implants and Thickness of Cortical Bone

Subjects: Allergy

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Dental implantation exhibits a high and predictable prevalence of success, but correct assessment of the relation between bone quality, primary stability and osseointegration of implants is still a major challenge. For example, the relationship between a denser thickness of cortical bone and implant stability has been the subject of low-quality clinical reports only, and this has not helped clinicians wishing to use this type of bone to design, prepare or place dental implants. Nevertheless, knowledge of this topic is important to refine the practice of dental implantation, as well as to minimize the risks of its failure.

dental implant primary stability secondary stability osseointegration cortical bone

1. Introduction

The first prerequisite for the success of dental implantation is represented by achieving sufficient primary stability. This is defined as the absence of mobility of the implant after insertion and is dependent upon mechanical engagement of the fixture with the surrounding bone [1][2][3]. During bone healing, insufficient primary stability can cause excessive micromotion (> 50–100 µm) at the bone–implant interface. Such micromotion can interfere with osseointegration and lead to the formation of fibrous scar tissue and hypertrophy of the surrounding trabecular bone [4]. Thus, achieving optimal primary stability prevents the formation of a connective-tissue layer between the fixture and bone. This action ensures secondary stability (also known as “biologic stability”), which is determined by the remodeling and functional regeneration of the bone surrounding the implant (i.e., osseointegration of the implant) [5][6].

Primary stability of the implant has been found to be dependent upon the surgical method (the relationship between the drill size and fixture size) and the microscopic/macroscopic morphology of the implant (i.e., shape, surface roughness) [1][7][8][9]. The quantity (thickness) and quality (density) of the bone at the implant site also influences primary stability [8],[9]. Differences in the outcomes of implant osseointegration may be justified by local differences in the anatomy and morphology of the bone. For example, the lower jaw shows a higher ratio of compact (cortical) bone to cancellous (trabecular) bone in comparison with the upper jaw [8]. Clinical studies have shown longer survival of the implant in the lower jaw than in the upper jaw because, in low-density bone, the primary stability of the implant has been demonstrated to be lower than that in high-density bone [10].

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relationship between a denser thickness of cortical bone and implant stability has been the subject of low-quality clinical reports only, and this has not helped clinicians wishing to use this type of bone to design, prepare or place dental implants. Nevertheless, knowledge of this topic is important to refine the practice of dental implantation, as well as to minimize the risks of its failure.

2. Measurements for Stability of Dental Implants

The assessment of primary stability at implantation represents a valid prognostic factor for a successful osseointegration. The primary stability of implants is commonly quantified by a non-invasive clinical method: the insertion torque (IT) test. Although IT is considered to be a reliable measure for the primary stability of implants, secondary stability cannot be assessed by a torque ratchet or by using IT-measuring “micromotors”.

The IT measurement can be obtained only upon implant placement. ISQ can be recorded in all phases of prosthetic treatment: upon fixture insertion, during the healing phase and even after the prosthesis has been loaded [11]. Hence, ISQ allows for implant stability to be assessed over time and represents a reliable measure of primary stability and secondary stability.

Although the most widespread methods for the evaluation of implant stability are IT measurement and RFA, another non-invasive device called the Periotest™ (Denti, Budapest, Hungary) can be used. Originally designed to determine tooth movement in a quantitative way, the Periotest value (PTV) assesses the increased stiffness of the implant–bone continuum over time. The range of PTV recorded for a clinically stable fixture is dependent upon the characteristics of the tissues around it (bone in the case of osseointegration and fibrous tissues in failed implants). Even minimal clinical mobility is considered a symptom of implant failure, so PTV evaluation may be of clinical interest [12]. However, PTV results are related strongly to the direction and position of excitation, so this evaluation method does not always measure a precise biomechanical parameter. Hence, Osstell™ (Osstell, Gothenburg, Sweden) is usually preferred for the assessment of implant stability [12].

IT and ISQ measure the bone–implant interaction in a different way, therefore, they provide different information [13]. To clarify this ambiguity, some clinicians have suggested to evaluate primary stability by measuring the insertion energy (IE), that is the amount of energy required to insert the implant into the site of interest [14][15]. Preliminary results have demonstrated that IE may be more reliable than RFA or IT to achieve acceptable primary stability even in softer bone [14] and is more reproducible at quantifying primary stability enhancement provided by under-preparation. However, the relationship between IE, RFA and IT has still to be investigated in depth [15].

3. Density and Quality of Bone

The quantity and quality of the host bone are determined by the crestal cortical bone thickness and the inner cancellous bone density, as well as by their relative distribution in the implant recipient site. Poor bone quantity and density are the main risk factors for fixture failure because they are related to excessive resorption of bone and impaired healing processes. Remarkably, the bone density at the implantation site has been shown to proportionally affect IT and ISQ: a higher density of local bone corresponds to a higher value of IT and ISQ [16]. This finding implies that clinical assessment of bone quality upon implantation plays a part in determining primary stability and subsequent osseointegration. Thus, it appears relevant to develop measurements of bone quality as a determinant for the successful outcome of endosseous implantation.

Bone quality was classified first by Lekholm and Zarb based on the morphology and distribution of cortical bone and trabecular bone. Four classes of residual alveolar bone were distinguished: type 1 (large homogenous cortical bone); type 2 (dense medullar bone surrounded by a thick cortical layer); type 3 (dense medullar bone surrounded by a thin cortical layer); type 4 (sparse medullar bone surrounded by a thin cortical layer). Lekholm and Zarb reported that the best outcome in implant therapy is obtained with a suitable amount of cortical thickness surrounding a cancellous region (type 1 and type 2 bone). Subsequently, a classification system developed by Misch was based on the perception of bone quality during drilling, which also provided comparative materials of different resistance to drilling to aid classification. This system identified five density groups (D1–D5) associated with specific locations of the jaw and tactile analogs (**Table 1**).

Table 1. Classification of bone density by Misch according to clinical drilling resistance of bone.

Bone Density	Description	Tactile Analog	Location
D1	Dense cortical bone	Oak wood	Anterior lower jaw
D2	Porous cortical bone and dense trabecular bone	Spruce wood	Anterior lower jaw Posterior lower jaw Anterior upper jaw
D3	Thin and porous cortical bone and thin trabecular bone	Balsa wood	Posterior lower jaw Anterior upper jaw Posterior upper jaw
D4	Thin trabecular bone	Styrofoam™	Posterior upper jaw
D5	Non-mineralized bone (unsuitable for implantation)	-	-

Thus, the use of CT became an objective method for the preoperative quantification of bone density, with several studies corroborating the relationship between CT measurements and the primary stability of the implant [17] [18]. However, concerns about radiation exposure to patients make CT a nonviable option for the routine measurement of bone density.

Several studies have positively correlated a higher prevalence of failure to implant placement into D4 bone. Conversely, good osseointegration is associated with implants placed into D1–D3 bone, thereby suggesting that D3 is the “ideal” type of bone for the adequate primary stability of implants. Overall, bone quality is regarded to be a key factor in planning implantation and the surgical procedure, as well as for defining the healing period and implant loading [19].

4. Thickness of Cortical Bone and Implant Stability

With the analogous purpose to guide optimal orthodontic mini-implant placement, characterization of cortical bone was conducted by CT rather than CBCT, and considered 60 high-resolution scans of the maxilla from patients unrelated to dental-implant treatment. That quantification study showed that the density and thickness of cortical bone increased significantly from the coronal (2 mm) to the apical (8 mm) areas of alveolar bone. The average thickness and density of cortical bone were found to be significantly higher in the palatal side rather than the buccal side, with the anterior maxillary region showing the greatest difference. The thickness and density of bone was positively correlated with BMI and age. Bone density (but not bone thickness) was shown to be associated with sex, data that were in accordance with the work from Gupta and colleagues [20] but not with results from Ono and collaborators [21].

Hence, a preoperative evaluation of cortical bone thickness at the implant site appears to be favorable to patients in terms of longer survival, but clinical research measuring this parameter is needed.

The relation between cortical bone thickness and secondary stability of the implant has not been studied deeply. A retrospective study by Tanaka and colleagues [22] investigated secondary stability in 113 patients (229 total implants) by RFA and ISQ, whereas the thickness of cortical bone at the insertion site was assessed preoperatively by CT. Mean ISQ after osseointegration was 75.99 ± 6.23, with implants showing significantly higher mean ISQ if placed into mandibular bone rather than maxillary bone, thereby suggesting a weak positive relation between cortical bone thickness and secondary stability of the fixture.

Conversely, a correlation between cortical bone thickness and ISQ, or MBL changes, were described by Dias and co-workers [23]. Evaluating a final sample of 31 patients (57 implants), ISQ and MBL determined by standardized periapical radiographs were registered at different phases of orthodontic treatment: implant insertion, uncovering/loading stage, and at 1-year follow-up. Those results are not in accordance with studies reporting significant relation between cortical bone thickness and implant stability [24],[25]. Different techniques of measuring CT images and a more in-depth assessment of the implant–cortical bone interaction, in relation also to the cortical bone preparation, might explain these controversial results, as well as the checkered evidence concerning high IT at insertion and late MBL.

References

1. Sennerby, L.; Roos, J; Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. *Int. J. Prosthodont.* **1998**, *11*, 408-420.
2. Miguel Gómez-Polo; Rocío Ortega; Cristina Gómez-Polo; Cristina Martín; Alicia Celemín; Jaime del Río; Does Length, Diameter, or Bone Quality Affect Primary and Secondary Stability in Self-

Tapping Dental Implants?. *Journal of Oral and Maxillofacial Surgery* **2016**, *74*, 1344-1353, 10.1016/j.joms.2016.03.011.

3. Carlos Cobo-Vázquez; David Reininger; Pedro Molinero-Mourelle; José González-Serrano; Blanca Guisado-Moya; Juan López-Quiles; Effect of the lack of primary stability in the survival of dental implants. *Journal of Clinical and Experimental Dentistry* **2017**, *10*, e14-e19, 10.4317/jced.54441.
4. J. Ziebart; S. Fan; C. Schulze; P. W. Kämmerer; R. Bader; A. Jonitz-Heincke; Effects of interfacial micromotions on vitality and differentiation of human osteoblasts. *Bone & Joint Research* **2018**, *7*, 187-195, 10.1302/2046-3758.72.bjr-2017-0228.r1.
5. Fawad Javed; Hameeda Bashir Ahmed; Roberto Crespi; Georgios E. Romanos; Role of primary stability for successful osseointegration of dental implants: Factors of influence and evaluation. *Interventional Medicine and Applied Science* **2013**, *5*, 162-167, 10.1556/imas.5.2013.4.3.
6. Roberto Crespi; Paolo Capparè; Elisabetta Maria Polizzi; Enrico Gherlone; Tissue remodeling after bone expansion in grafted and ungrafted sockets.. *The International Journal of Oral & Maxillofacial Implants* **2014**, *29*, 699-704, 10.11607/jomi.3535.
7. Dominic O'sullivan; Lars Sennerby; Daryll Jagger; Neil Meredith; A comparison of two methods of enhancing implant primary stability.. *Clinical Implant Dentistry and Related Research* **2004**, *6*, 48-57, 10.1111/j.1708-8208.2004.tb00027.x.
8. M. Sevimay; F. Turhan; Mehmet Ali Kılıçarslan; G. Eskitascioglu; Three-dimensional finite element analysis of the effect of different bone quality on stress distribution in an implant-supported crown. *The Journal of Prosthetic Dentistry* **2005**, *93*, 227-234, 10.1016/j.prosdent.2004.12.019.
9. Afsheen Tabassum; Gert J. Meijer; Johannes G. C. Wolke; John A. Jansen; Influence of surgical technique and surface roughness on the primary stability of an implant in artificial bone with different cortical thickness: a laboratory study. *Clinical Oral Implants Research* **2010**, *21*, 213-220, 10.1111/j.1600-0501.2009.01823.x.
10. N. Farre-Pages; Ml. Auge-Castro; F. Alaejos-Algarra; J. Mareque-Bueno; Eduard Ferrés-Padró; F. Hernandez-Alfaro; Relation between bone density and primary implant stability. *Medicina Oral Patología Oral y Cirugia Bucal* **2011**, *16*, e62-e67, 10.4317/medoral.16.e62.
11. Barry Levin; The Correlation Between Immediate Implant Insertion Torque and Implant Stability Quotient. *The International Journal of Periodontics & Restorative Dentistry* **2016**, *36*, 833-840, 10.11607/prd.2865.
12. Samer Al-Jetaily; Abdullah AlFarraj Al-Dosari; Assessment of Osstell™ and Periotest® systems in measuring dental implant stability (in vitro study). *The Saudi Dental Journal* **2011**, *23*, 17-21, 10.1016/j.sdentj.2010.09.003.

13. Lars Sennerby; Neil Meredith; Implant stability measurements using resonance frequency analysis: biological and biomechanical aspects and clinical implications. *Periodontology 2000* **2008**, *47*, 51-66, 10.1111/j.1600-0757.2008.00267.x.
14. Marco Degidi; Giuseppe Daprile; Adriano Piattelli; Giovanna Iezzi; Development of a New Implant Primary Stability Parameter: Insertion Torque Revisited. *Clinical Implant Dentistry and Related Research* **2011**, *15*, 637-644, 10.1111/j.1708-8208.2011.00392.x.
15. K.-J. Park; J.-Y. Kwon; S.-K. Kim; Seong Joo Heo; J.-Y. Koak; J.-H. Lee; Shin-Jae Lee; T.-H. Kim; M.-J. Kim; The relationship between implant stability quotient values and implant insertion variables: a clinical study. *Journal of Oral Rehabilitation* **2011**, *39*, 151-159, 10.1111/j.1365-2842.2011.02255.x.
16. Christian Makary; Abdallah Menhall; Carole Zammarie; Teresa Lombardi; Seung Yeup Lee; Claudio Stacchi; Kwang Bum Park; Primary Stability Optimization by Using Fixtures with Different Thread Depth According To Bone Density: A Clinical Prospective Study on Early Loaded Implants. *Materials* **2019**, *12*, 2398, 10.3390/ma12152398.
17. Ilser Turkyilmaz; Lars Sennerby; Edwin A. McGlumphy; Tolga F. Tözüm; Biomechanical Aspects of Primary Implant Stability: A Human Cadaver Study. *Clinical Implant Dentistry and Related Research* **2009**, *11*, 113-119, 10.1111/j.1708-8208.2008.00097.x.
18. Murat Cavit Çehreli; Ali Murat Kökat; Ayhan Comert; Murat Akkocaoglu; Ibrahim Tekdemir; Kıvanç Akça; Implant stability and bone density: assessment of correlation in fresh cadavers using conventional and osteotome implant sockets. *Clinical Oral Implants Research* **2009**, *20*, 1163-1169, 10.1111/j.1600-0501.2009.01758.x.
19. Igor Linetskiy; Vladyslav Demenko; Larysa Linetska; Oleg Yefremov; Impact of annual bone loss and different bone quality on dental implant success – A finite element study. *Computers in Biology and Medicine* **2017**, *91*, 318-325, 10.1016/j.compbiomed.2017.09.016.
20. Ajai Gupta; Suprabha Rathee; JaiHans Agarwal; Renu B Pachar; Measurement of Crestal Cortical Bone Thickness at Implant Site: A Cone Beam Computed Tomography Study. *The Journal of Contemporary Dental Practice* **2017**, *18*, 785-789, 10.5005/jp-journals-10024-2127.
21. A. Ono; M. Motoyoshi; N. Shimizu; Cortical bone thickness in the buccal posterior region for orthodontic mini-implants. *International Journal of Oral and Maxillofacial Surgery* **2008**, *37*, 334-340, 10.1016/j.ijom.2008.01.005.
22. Kenko Tanaka; Irena Sailer; Ryosuke Iwama; Kensuke Yamauchi; Shinnosuke Nogami; Nobuhiro Yoda; Tetsu Takahashi; Relationship between cortical bone thickness and implant stability at the time of surgery and secondary stability after osseointegration measured using resonance frequency analysis. *Journal of Periodontal & Implant Science* **2018**, *48*, 360-372, 10.5051/jpis.2018.48.6.360.

23. Danilo Rocha Dias; Cláudio Rodrigues Leles; Christina Lindh; Rejane Faria Ribeiro-Rotta; Marginal bone level changes and implant stability after loading are not influenced by baseline microstructural bone characteristics: 1-year follow-up. *Clinical Oral Implants Research* **2015**, *27*, 1212-1220, 10.1111/clr.12728.
24. Ikuya Miyamoto; Yoichi Tsuboi; Eishin Wada; Hirohiko Suwa; Tadahiko Iizuka; Influence of cortical bone thickness and implant length on implant stability at the time of surgery—clinical, prospective, biomechanical, and imaging study. *Bone* **2005**, *37*, 776-780, 10.1016/j.bone.2005.06.019.
25. Joe Merheb; Nele Van Assche; Wim Coucke; Reinhilde Jacobs; Ignace Naert; Marc Quirynen; Relationship between cortical bone thickness or computerized tomography-derived bone density values and implant stability. *Clinical Oral Implants Research* **2010**, *21*, 612-617, 10.1111/j.1600-0501.2009.01880.x.