International Journal of Research in Medical Sciences
Raghavan R et al. Int J Res Med Sci. 2025 Sep;13(9):3904-3907
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20252818

Review Article

The critical role of bone density in implant dentistry: a review article

Rohit Raghavan, Shajahan P. A., B. M. Rajsree*

Department of Prosthodontics, Royal Dental College, Chalissery, Palakkad, Kerala, India

Received: 22 June 2025
Revised: 01 August 2025
Accepted: 19 August 2025

***Correspondence:**
Dr. B. M. Rajsree,
E-mail: rajsreebm96@gmail.com

ABSTRACT

Bone density is a crucial factor for the success of dental implants. A strong, dense jawbone provides the necessary foundation for the implant to fuse with the surrounding bone, a biological process called osseointegration. This direct connection between the implant and the bone is what makes it stable and ensures it lasts a long time. Without adequate bone density, which can be compromised by systemic conditions like osteoporosis or localized bone loss, the implant lacks a solid anchor. This can lead to poor primary stability, delayed healing, and a significantly higher risk of failure. To precisely assess this critical parameter, dentists rely on a classification system, such as the Misch classification, which categorizes bone quality into four distinct types, from D1 (dense cortical bone) to D4 (very fine trabecular bone). This detailed evaluation is essential as it directly informs the surgical procedure, guiding the clinician in selecting the optimal implant design and placement technique to ensure a predictable and successful outcome.

Keywords: Bone density, Bone-implant contact, Implant success

INTRODUCTION

The internal and external structure of bone significantly influences every aspect of implant dentistry. Bone density is a crucial factor in planning the surgical procedure and predicting the success of an implant. The density of bone at the implant site directly affects treatment decisions, the surgical method used, the type of implant chosen, the healing period, and whether the bone needs to be gradually loaded with a prosthetic during reconstruction.[1]

ETIOLOGY OF VARIABLE BONE DENSITY

Bone is an organ that constantly adapts to its environment. While factors like hormones and vitamins play a role, its physical structure is primarily shaped by biomechanical parameters. The amount of stress, or strain, placed on the bone is the most significant factor in how it changes and develops.[2] According to MacMillan and Parfitt, the trabeculae, or internal bone structures, in the alveolar regions of the jaw have unique characteristics and variations. The maxilla (upper jaw) and mandible differ in their biomechanics. The mandible, being a separate structure, is specifically designed to absorb and handle force.[3]

When teeth are present, the mandible's outer layer of bone (cortical bone) is thicker and denser, and its inner spongy bone (trabecular bone) is coarser and more compact. The maxilla, however, functions differently, acting as a unit to distribute force. As a result, it has a thinner cortical plate and finer trabecular bone surrounding the teeth.[4]

MISCH BONE DENSITY CLASSIFICATION

The Misch classification system categorizes the density of jawbone in areas where teeth are missing into four primary types, D1 through D4. This classification helps clinicians determine the best approach for dental implant placement.

D1 bone

This is the densest type of bone, consisting almost entirely of dense cortical bone.

D2 bone

This type features a thick layer of dense to porous cortical bone on the outside, surrounding a core of coarse trabecular (spongy) bone.

D3 bone

Characterized by a thinner and more porous outer cortical layer, with the inner region containing fine trabecular bone.

D4 bone

The softest of the four main types, D4 bone has very little or no outer cortical bone, with the majority of its volume made up of fine, porous trabecular bone.

D5 bone

A fifth category, D5 bone, is sometimes used to describe very soft bone that is not yet fully mineralized. This type is often found in newly developing bone graft sites where the bone is still immature.

BONE DENSITY: LOCATION

Studies on patients with dental implants show a strong link between bone density, implant success, and location within the jaw. The density of bone often correlates with specific regions of the mouth, which directly impacts the predictability of treatment. While a more precise measure of bone density can be obtained pre-surgically with a computed tomography (CT) scan, a surgeon can also assess it by feel during the procedure. The densest bone, D1, is typically in the anterior mandible; D2 bone is common in the anterior maxilla and posterior mandible; D3 bone is most often found in the posterior maxilla and mandible; and the softest bone, D4, is primarily located in the posterior maxilla.[5]

RADIOGRAPHIC BONE DENSITY

Standard radiographs, such as periapical or panoramic X-rays, are not very effective for accurately measuring bone density. This is because the dense outer layers of bone (cortical plates) often hide the details of the softer, internal spongy bone (trabecular bone). These X-rays also can't detect the subtle differences between bone types like D2 and D3. For this reason, an initial treatment plan based on these images often relies on the general bone density expected in a specific area of the jaw.[6]

BONE DENSITY-TACTILE SENSE

Misch proposed using an analogy to help dental professionals understand the tactile sensation of drilling into different bone densities. Because the strength of the bone is directly related to its density, a surgeon can feel a significant difference during an osteotomy. To standardize this feeling and make it easier to communicate, Misch compared his bone density classifications (D1, D2, D3, D4) to the sensation of drilling into various materials, helping practitioners better assess bone quality and plan their procedures.

BONE DENSITY AND BONE–IMPLANT CONTACT PERCENTAGE

Initial bone density is important for two key reasons: it provides mechanical stability for the implant while it heals, and it allows for the proper transfer of forces from the prosthetic crown to the surrounding bone after healing is complete. Stress from a dental implant is primarily transferred to the jawbone at the points where the two surfaces are in direct contact. This bone-to-implant contact is much greater in dense cortical bone than in softer trabecular bone.

This is a critical factor for implant success. For example, the anterior or posterior mandible, which has the densest bone, can provide over 85% bone-to-implant contact. Following initial healing, D2 bone usually fuses with the implant at a rate of 65% to 75%, while D3 bone's integration rate is typically lower, at 40% to 50%.The softest bone, D4, often found in the posterior maxilla, has sparse trabeculae and offers less than 30% contact. This percentage is highly dependent on bone density, healing time, and the implant's design and surface.

A study by Carr et al found that the bone surrounding an implant was more in contact with the implant in the denser bone of the mandible compared to the maxilla. Furthermore, they observed that this contact improved significantly between three and six months in both jaws. This suggests that extending the healing time before an implant is loaded, particularly in regions with lower bone density, leads to better osseointegration and a stronger final result.[8]

BONE DENSITY AND STRESS TRANSFER

Excessive stress where the implant meets the bone can lead to bone loss at the crest and early implant failure after it's been restored. The amount of bone loss varies significantly across different bone densities, even when similar forces are applied. A study by Misch in 1990 used finite element analysis (FEA) to explain this.[4] Their models simulated the properties of each of the four bone densities and showed that under normal chewing loads, implant failure could be mathematically predicted in the softer D4 bone and some D3 densities.

The way stress is distributed around an implant varies significantly with bone density. In dense D1 bone, the greatest stress is focused at the top of the implant near the crest. When the same force is applied to D2 bone, the stress at the crest is a little higher, and the intense pressure extends further down the implant's body. The softest D4 bone, the crestal strains are the greatest, and the stress is distributed furthest down the implant, making it more vulnerable to failure.

TREATMENT PLANNING

Initial examinations for dental implant patients often rely on a panoramic radiograph to form a preliminary treatment plan. This plan uses a general assumption of bone density based on the location in the jaw: the anterior mandible is typically assumed to have D2 bone, the anterior maxilla and posterior mandible are considered to have D3 bone, and the posterior maxilla is treated as having the softest D4 bone. This method provides a starting point for discussion with the patient, linking the anatomical region to the expected bone quality.

Once an initial treatment plan is established, a more detailed and accurate plan for dental implants is created by either performing a CT scan or by a surgeon's tactile assessment during the procedure. Bone density modifies the treatment plan in several key ways, influencing factors such as the type of prosthesis used, the number and size of implants needed, the implant's design and surface, and whether a progressive loading protocol is required.[9] As bone density decreases, so does its strength, making it more susceptible to microfractures. To prevent this, the stress on the bone needs to be reduced. Since stress and strain are directly related, the load on the implant system must be decreased as bone quality declines. One effective way to reduce this stress is by increasing the functional surface area over which the force is distributed. Therefore, using more implants is an excellent strategy to achieve this by spreading the functional load more widely.[10] Using three implants instead of two can significantly reduce the forces applied to the implants and the surrounding bone, potentially cutting the implant moments by half and bone reaction forces by two-thirds.[11] This depends on the size and placement of the implants. For patients with soft D4 bone, it's often best to place at least one implant for every missing tooth. In the molar region, where chewing forces are greatest, using two implants for a single missing molar may be a more appropriate strategy.

Using three implants instead of two can significantly reduce the forces applied to the implants and the surrounding bone, potentially cutting the implant moments by half and bone reaction forces by two-thirds. This depends on the size and placement of the implants. For patients with soft D4 bone, it's often best to place at least one implant for every missing tooth.[12] In the molar region, where chewing forces are greatest, using two implants for a single missing molar may be a more appropriate strategy. Because the greatest stresses are concentrated at the crestal region of the implant in good bone types, width is more significant than length for an implant design after adequate length has been established. D4 bone should often require wider implants compared with D1 or D2 bone. Based on long-term clinical experience of V-shaped threaded implant bodies, the minimum bone height for initial fixation and early loading for D1 bone is 7 mm for D2 bone, 9 mm and for D3 bone, 12 mm using the classic V-thread screw implant design and titanium surface condition. Because the crestal region is where pathologic overload of bone most often occurs after prosthetic loading, after initial healing is complete, the length of the implant is not as effective to solve crestal bone loss (and the quality of implant health) as other factors (e.g., implant design, implant width). D4 bone benefits from relatively longer implants for initial fixation and early loading compared with other bone densities, not only for initial fixation but also because the stress–strain transfer of occlusal forces extends farther down the implant body.[13]

Given how stress is distributed, longer implants (12-15 mm) are often recommended for softer bone types. In dense D1 bone, the highest stress is focused at the implant's crest, while in D2 bone, the stress is slightly higher and extends further down. However, in the softest D4 bone, stress is at its maximum and is distributed farthest down the implant body, making it more prone to failure. To address this, implants for soft bone should be designed with more and deeper threads to increase the surface area for bone contact. Additionally, a rougher implant surface, which has been shown to improve survival rates in soft bone, is often preferred over a smooth, machined surface to enhance bone-to-implant contact, although it may have some disadvantages.[14] While rough implant surfaces can improve survival rates, they also come with drawbacks, including plaque retention, potential contamination, and higher costs. For this reason, the roughest surfaces are typically reserved for softer bone types where their benefits outweigh the risks. Another way to manage biomechanical stress on implants is through prosthesis design, which can help decrease the force transmitted to the bone.

Removable prostheses (RP-4), which patients can take out at night, are useful for reducing destructive forces from night time teeth grinding. Another type, the RP-5 prosthesis, is designed to allow the surrounding soft tissue to share the load, thereby reducing stress on the implants. The direction of force also matters: a load applied along the long axis of the implant creates less stress on the crestal bone than an angled load. Therefore, as bone density decreases, ensuring axial loading becomes even more critical for success.[15] Progressive bone loading is a technique that involves gradually increasing the occlusal forces on an implant over time. This approach allows the bone to mature and adapt to the local stress environment, which can improve long-term integration and stability.

CONCLUSION

Accurately diagnosing the bone density at a potential implant site is a key factor for clinical success, as bone strength is directly related to its density. To ensure a successful outcome, the treatment plan can be adjusted in several ways: by reducing the force on the prosthesis or by increasing the area over which the load is applied. This can be achieved by using more implants, increasing their size or width, choosing a different implant design, or selecting an implant with a specific surface condition.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Misch CE. Available bone influences prosthodontic treatment, Dent Today. 1988;7(1):44-75.
2. Misch CE. Bone density: a key determinant for treatment planning. In Misch CE, editor: Contemporary implant dentistry, ed 3, St Louis. Elsevier Mosby. 2008; 130-146.
3. Misch CE. Bone character: second vital implant criterion. Dent Today. 1988;7:39-40.
4. Misch CE. Density of bone: effect on treatment plans, surgical approach, healing, and progressive loading, Int J Oral Implantol. 1990;6:23-31.
5. Turkyilmaz I, McGlumphy EA. Influence of bone density on implant stability parameters and implant success: a retrospective clinical study. BMC Oral Health. 2008;8:32.
6. Friberg B, Jemt T, Lekholm U. Early failures in 4,641 consecutively placed Branemark dental implants. A study from stage I surgery to the connection of completed prosthesis. Int J Oral Maxillofac Implants. 1991;6:142-6.
7. Jemt T, Lekholm U. Implant treatment in edentulous maxilla: a 5-year follow-up report on patients with different degrees of jaw resorption. Int J Oral Maxillofac Implants. 1995;10:303-11.
8. Norton MR, Gamble C. Bone classification: an objective scale of bone density using the computerized tomography scan. Clin Oral Implants Res. 2001;12:79-84.
9. Gomes Olieveira RC, Leles CR, Normanha LM, Lindh C, Ribeiro-Rotta RF. Assessments of trabecular bone density at implant sites on CT images. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;105(2):231-8.
10. Tumer TI, Ozbek EN, Tozum TF. Relations between the bone density from computerized tomography, and implant stability parameters: a clinical study of 230 regular platform implants. J Clin Periodontol. 2007;34:716-22.
11. Beer A, Gahleitner A, Tschabitscher A, Homolka P. Correlation of insertion torques with bone mineral density from dental quantitative CT in the mandible. Clin Oral Implants Res. 2003;14:616-20.
12. Hanazawa T, Sano T, Seki K, Okano T. Radiographic measurements of the mandible: a comparison between CT-reformatted and conventional tomographic images. Clin Oral Implants Res. 2004;15:226-32.
13. Strietzel FP, Nowak M, Kuchler I, Friedmann A. Peri-implant alveolar bone loss with respect to bone quality after use of osteotomes technique. Clin Oral Implants Res. 2002;13:508-13.
14. Davapanah M, Martinez H, Tecucianu JF, Hage G, Lazzara R. The modified osteotome technique. Int J Periodontics Restorative Dent. 2001;21:599-607.
15. Shapurian T, Damoulis PD, Reiser GM, Griffin TJ, Rand WM. Quantitative evaluation of bone density using the Hounsfield index. Int J Oral Maxillofac Implants. 2006;21:290-7.

Cite this article as: Raghavan R, Shajahan PA, Rajsree BM. The critical role of bone density in implant dentistry: a review article. Int J Res Med Sci 2025;13:3904-7.