

# Drilling speed and bone healing in implantology: evidence-based recommendations

## Abstract

Drilling speed is a critical factor in implantology that influences multiple dimensions of surgical and post-surgical success, including bone healing, osseointegration, and the prevention of thermal damage. This article comprehensively examines the relationship between drilling speed and bone physiology, drawing on recent research to provide actionable, evidence-based guidelines for clinicians. By emphasizing the balance between efficiency and tissue preservation, the article underscores key strategies for minimizing thermal damage, optimizing primary stability, and enhancing long-term implant success. These recommendations are designed to support practitioners in achieving superior clinical outcomes while safeguarding bone vitality.

**Keywords:** implantology, drilling speed, bone healing, osseointegration

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## Introduction

Dental implant success relies heavily on the precise preparation of the implant site. Among the factors that determine the quality of this preparation, drilling speed plays a pivotal role. The speed of drilling affects bone temperature, cellular viability, and the mechanical properties of the prepared site. Excessive heat generation during drilling can lead to thermal necrosis, compromising the healing process and implant stability. Moreover, the mechanical trauma associated with improper drilling speeds can delay the bone healing cascade, negatively impacting osseointegration.<sup>1</sup> This article reviews the effects of drilling speed on bone healing and provides recommendations for optimizing surgical protocols.

## The effect of drilling speed on bone physiology

### Thermal effects on bone

Bone is highly sensitive to temperature changes. Studies have consistently shown that temperatures exceeding 47°C for more than one minute can cause irreversible damage to bone cells and proteins, leading to thermal necrosis.<sup>2</sup> Such damage compromises the bone's ability to support osseointegration, significantly reducing implant success rates.

High-speed drilling, particularly in dense cortical bone, generates significant heat. Without adequate mitigation measures, such as copious irrigation, this heat can quickly exceed safe thresholds. Irrigation plays a critical role in dissipating this heat and maintaining the cellular integrity of the surrounding bone.<sup>3</sup>

The depth of thermal damage can vary depending on the type of bone. Dense cortical bone is more susceptible to heat-related damage due to its lower vascularity and slower heat dissipation, making the use of lower speeds and effective cooling essential.<sup>4</sup>

Advanced surgical tools, such as thermally controlled drills and infrared thermography, are now being employed to monitor and manage bone temperature during the drilling process. These tools enable real-time adjustments to minimize thermal risk and ensure optimal surgical outcomes.<sup>5</sup> Bone is highly sensitive to temperature changes.

## Bone microstructure and stability

The integrity of bone microstructure plays a crucial role in the stability and success of dental implants. During implant site preparation, drilling speed significantly impacts the bone's physical characteristics, influencing primary stability and long-term outcomes.

At lower drilling speeds, the bone surface tends to retain a rougher texture. This micro-roughness enhances mechanical interlocking between the bone and the implant, facilitating higher insertion torque and better resistance to micromovement during the healing phase.<sup>4</sup> This is especially critical for ensuring primary stability, which directly affects osseointegration—the biological process where the bone grows and integrates with the implant surface.

Conversely, high-speed drilling can smoothen the bone surface, potentially diminishing the implant's ability to achieve robust mechanical engagement. This effect is more pronounced in dense cortical bone, where slower speeds and careful irrigation are recommended to preserve the bone's natural texture and vitality.<sup>5</sup>

Additionally, the preservation of bone microstructure is vital for promoting the bone remodeling process, which strengthens the bone-implant interface over time. Studies indicate that implants placed in sites prepared with slower drilling speeds exhibit improved outcomes in terms of bone-to-implant contact and reduced marginal bone loss.

## Osseointegration

Maintaining bone vitality during drilling is paramount to the success of osseointegration, the biological process by which the implant integrates with the surrounding bone. This process depends on the preservation of bone cells, proteins, and the overall structural integrity of the bone during implant site preparation. Excessive heat and mechanical trauma caused by improper drilling speeds can severely disrupt the bone healing cascade, potentially leading to delayed or incomplete osseointegration.

Studies have shown that slower drilling speeds, ranging between 400-800 Revolutions Per Minute (RPM), combined with effective cooling mechanisms, significantly enhance osseointegration outcomes. By minimizing thermal damage, these protocols help

preserve the osteocytes and bone matrix, creating an environment conducive to new bone formation and integration with the implant surface.<sup>6</sup>

Additionally, the surface characteristics of the drilled site play a vital role in this process. Rougher bone surfaces created by lower-speed drilling promote better mechanical interlocking between the bone and implant, increasing primary stability. This mechanical stability provides a foundation for the biological processes required for osseointegration to occur effectively.

Moreover, the success of osseointegration is closely linked to the control of inflammation and early bone remodeling. Lower drilling speeds help maintain the natural balance of these processes, ensuring a faster and more robust integration of the implant into the bone. These findings underscore the importance of adopting evidence-based drilling protocols tailored to the specific characteristics of each patient's bone density and quality.

## Optimal drilling speed: evidence and guidelines

### Low-speed drilling

- Low-speed drilling, typically ranging from 400-800 RPM, is widely recognized as a safer option for preserving bone health during implant site preparation. At these speeds, heat generation is minimized, significantly reducing the risk of thermal necrosis, a condition where excessive heat damages bone tissue and disrupts its ability to heal and regenerate.<sup>7</sup>
- The primary advantage of low-speed drilling is the preservation of bone vitality. By generating less heat, low-speed drilling ensures that the osteocytes and bone matrix remain intact, providing an optimal environment for osseointegration—the critical process where the implant becomes securely integrated into the bone.<sup>8</sup>
- Furthermore, lower speeds result in a rougher bone surface at the implant site. This micro-roughness promotes better mechanical interlocking between the implant and the bone, enhancing primary stability. Studies have shown that implants placed in low-speed-prepared sites exhibit higher insertion torque and reduced micromovement, both of which are crucial for long-term success.<sup>9</sup>
- However, low-speed drilling is not without its challenges. The longer procedural time required for site preparation may lead to operator fatigue, particularly in complex cases involving dense cortical bone. Additionally, the slower drilling process can necessitate more irrigation to prevent heat build-up over extended periods, requiring meticulous technique and attention to detail from the clinician.<sup>10</sup>
- In summary, while low-speed drilling demands greater effort and time, its benefits for bone preservation and implant stability make it a preferred choice in many clinical scenarios. By combining low speeds with adequate irrigation and sharp drills, practitioners can maximize the success rate of dental implants while safeguarding bone health.

### High-speed drilling

High-speed drilling, typically exceeding 1,500 RPM, (For example *OsseoSpeed EV Implant System* by Astra Tech) is often utilized in implant site preparation for specific scenarios, such as working with

soft cancellous bone or requiring rapid site preparation. The primary advantage of high-speed drilling is its efficiency, significantly reducing procedural time, which can be especially beneficial in complex or multi-implant cases.

However, the increased speed comes with significant risks, particularly the potential for thermal damage to the surrounding bone. Rapid rotation generates substantial heat, especially in dense cortical bone, where the risk of surpassing safe temperature thresholds (>47°C) is heightened. Without adequate irrigation, this heat can lead to thermal necrosis, jeopardizing osseointegration and long-term implant stability.

Additionally, high-speed drilling tends to create smoother bone surfaces at the implant site, which may reduce the mechanical interlocking required for primary stability. This is in contrast to the rougher surfaces produced by slower drilling speeds, which are more conducive to bone remodeling and integration.

To mitigate these risks, clinicians must ensure copious irrigation during high-speed drilling to dissipate heat effectively. Furthermore, the use of advanced thermally controlled drills and adherence to adaptive protocols-adjusting speed based on the bone density and anatomical location- can help optimize outcomes. While high-speed drilling offers efficiency, careful technique and cooling measures are essential to prevent complications and ensure successful implant integration. Speeds exceeding 1,500 RPM are generally used for soft cancellous bone or for rapid site preparation in non-critical areas.

### Variable speed drilling protocols

Variable speed drilling protocols have emerged as a cornerstone in modern implantology, offering tailored approaches to optimize outcomes based on specific clinical scenarios. These protocols adapt drilling speeds to bone density, anatomical location, and patient-specific factors, ensuring a balance between efficiency and bone preservation.

For dense cortical bone, lower speeds (400-600 RPM) are recommended to minimize heat generation and protect the bone's structural integrity. These speeds, combined with copious irrigation, help dissipate heat effectively, reducing the risk of thermal necrosis. The slower speeds also create a rougher bone surface, enhancing mechanical interlocking and improving primary stability.

In softer cancellous bone, moderate to higher speeds (800-1,200 RPM) are preferred. These speeds facilitate efficient material removal while maintaining bone vitality. Higher speeds in such cases prevent excessive pressure on the drill, reducing the risk of micro-fractures or over-compaction of bone.

Adaptive protocols often utilize advanced technologies, such as dynamic drill systems and real-time feedback mechanisms, to monitor and adjust speeds during surgery. These tools allow clinicians to respond to variations in bone quality and density, ensuring optimal outcomes. By combining variable speeds with precision irrigation and sharp drill bits, practitioners can significantly enhance the safety and success of implant procedures.

Ultimately, variable speed drilling protocols provide a versatile framework for addressing the diverse challenges of implant site preparation. By tailoring the approach to individual patient needs, clinicians can achieve superior implant stability, reduced complications, and improved long-term results.

## Recommendations for bone healing in implantology

Optimizing bone healing during implant procedures requires a multifaceted approach grounded in evidence-based strategies. Below are the key recommendations for achieving successful outcomes:

### Ensure adequate irrigation

Continuous and copious irrigation using saline or sterile coolant is essential to dissipate heat generated during drilling. Adequate irrigation helps maintain bone temperature below the critical threshold of 47°C, preventing thermal necrosis and preserving bone vitality.<sup>10</sup> Research highlights that irrigation delivered consistently at the drilling site enhances cooling efficiency, particularly in dense cortical bone where heat dissipation is slower.

### Use sharp drills

Sharp drills reduce friction, ensuring efficient cutting and minimizing heat generation. Blunt or worn drills can significantly increase drilling time and elevate bone temperature, compromising osseointegration.<sup>11</sup> Regular maintenance, sterilization, and timely replacement of drill bits are critical for sustaining their performance and ensuring safe surgical practices.

### Adopt variable speed protocols

Tailoring drilling speeds to bone density and anatomical conditions can improve outcomes. For dense cortical bone, lower speeds (400-600 RPM) minimize heat production and maintain the structural integrity of the bone. For softer cancellous bone, moderate to higher speeds (800-1,200 RPM) facilitate efficient material removal while preserving bone vitality.<sup>12</sup> These protocols allow clinicians to optimize drilling efficiency without sacrificing patient safety, creating the ideal environment for primary stability and osseointegration.

### Monitor bone temperature

Advanced technologies, such as infrared thermography and dynamic drill systems, enable real-time monitoring of bone temperature. These tools provide immediate feedback, allowing clinicians to make necessary adjustments to speed, pressure, or irrigation.<sup>13</sup>

Maintaining intraoperative control over thermal conditions ensures that bone remains within safe temperature limits throughout the procedure.

### Operator training and precision

Comprehensive training in drilling techniques, speed control, and thermal management is critical for practitioners to reduce complications and enhance surgical outcomes. Training programs should emphasize the importance of balancing efficiency with bone preservation.<sup>14</sup> Precision in handling equipment and adhering to standardized protocols ensures consistency in patient outcomes and minimizes risks associated with improper drilling techniques.

These recommendations collectively emphasize the importance of a patient-centered approach that considers individual bone quality, surgical complexity, and technological advancements. By implementing these strategies, clinicians can achieve superior implant stability, reduced complications, and long-term success.

## Conclusion

Drilling speed is a key determinant of successful dental implant placement. By optimizing drilling protocols to balance efficiency and bone preservation, clinicians can ensure improved bone healing, enhanced primary stability, and long-term implant success. Adopting evidence-based strategies such as variable speed drilling, adequate irrigation, and the use of sharp drills will help minimize thermal damage and maximize clinical outcomes. Continued research into the interplay between drilling parameters and bone physiology will further refine surgical guidelines in implantology. Incorporating advanced technologies and adhering to best practices will ensure predictable and superior outcomes for patients.<sup>15-17</sup>

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## Conflict of interests

The authors declare that there are no conflicts of interest.

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