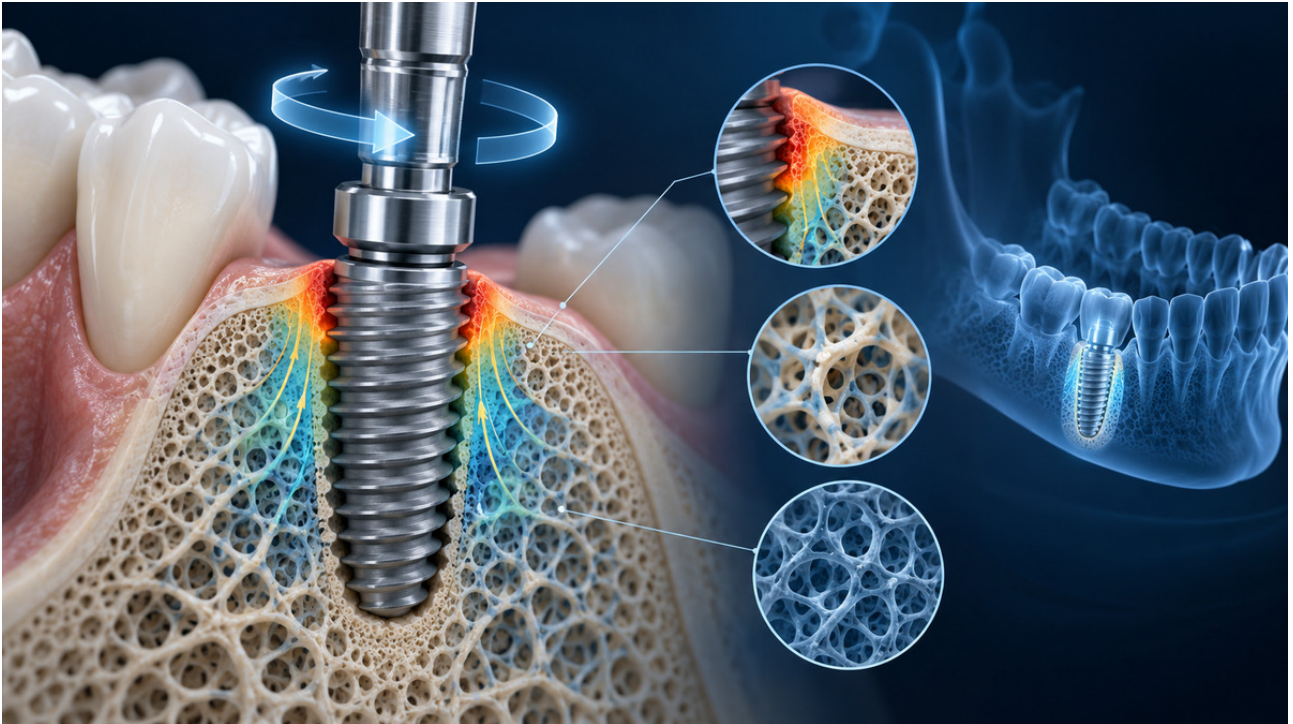


Primary Stability Without Overcompression: Insertion Torque, Bone Mechanics and Loading Decisions

How osteotomy preparation, implant design and site-specific resistance shape safe implant placement



Core message: insertion torque is one measure of rotational resistance at placement. It helps describe primary stability, but it does not independently predict osseointegration. The objective is adequate stability with preservation of bone vitality, not the highest possible torque.

Educational material for dental students, postgraduate trainees and academic teachers

Primary stability is mechanical

Primary stability is the mechanical resistance of an implant immediately after placement. It limits micromotion during the earliest phase of healing. Secondary stability develops later through bone formation, remodelling and maturation at the interface.

Component	What it reflects	Clinical meaning
Insertion torque	Rotational resistance while the implant advances through the osteotomy.	Sensitive to cortical engagement, implant geometry, preparation and friction.
Resonance frequency analysis	Stiffness of the implant-bone complex under lateral excitation, reported as ISQ.	Influenced by implant length, diameter, exposed height and surrounding bone.
Periotest or damping methods	Dynamic response of the implant to a mechanical impulse.	Can complement other measures but depends on angulation and measurement conditions.
Clinical mobility	Gross movement detected manually or instrumentally.	Mobility at placement signals inadequate fixation and changes the treatment plan.
Surgical perception	Resistance during drilling and placement.	Useful contextual information but operator-dependent and difficult to standardize.

Different tools measure different properties

Insertion torque and RFA may correlate weakly or moderately because rotational friction and lateral stiffness are not the same mechanical phenomenon. A high value in one measure does not guarantee a high value in the other.

Interpretation principle: use several observations when the loading decision is consequential. One number cannot summarize interface mechanics, bone biology and prosthetic risk.

Where insertion torque comes from

Torque develops from cutting, thread engagement, friction and compression as the implant advances. The final peak value is shaped by the entire implant-site system rather than by bone density alone.

Determinant	Effect on torque	Planning implication
Cortical thickness	Thicker cortex often increases coronal resistance.	Consider crestal preparation when the manufacturer permits it.
Trabecular architecture	Sparse trabeculation can reduce apical and body engagement.	Adapt osteotomy and implant design without creating uncontrolled compression.
Osteotomy diameter	A smaller preparation generally increases interference and torque.	Undersizing must remain system- and site-specific.
Implant macrogeometry	Taper, thread depth, pitch and cutting features alter engagement.	Torque values cannot be transferred directly between implant designs.
Implant diameter and length	Change contact area and the regions that contribute resistance.	Select dimensions from anatomy and prosthetic need, not torque alone.
Insertion speed and technique	May affect friction, heat and measurement trajectory.	Follow the validated surgical protocol and calibrated equipment.
Site preparation quality	Drill wear, runout and irrigation influence the osteotomy.	Inspect instruments and record deviations from the planned sequence.

The torque curve contains more information than the last value

A rapid rise near the crest can indicate dominant cortical resistance. A gradual increase may reflect progressive thread engagement. An unexpected spike can signal underpreparation, binding, debris or a mismatch between implant and osteotomy. If the system records the curve, it can support interpretation, but standardized clinical thresholds remain limited.

Do not compare unlike systems: the same numerical torque can arise from different implant designs, osteotomies and bone architectures.

Measurement limits and documentation

Torque is usually recorded as a peak value in Ncm, but measurement accuracy depends on the motor, handpiece, wrench and calibration. A displayed number should not be treated as exact if the device resolution and maintenance are unknown.

Issue	Potential error	Control
Motor calibration	Displayed torque can differ from delivered torque.	Use scheduled calibration and manufacturer maintenance.
Manual wrench	Operator speed and reading method can affect the result.	Use the intended device and document manual measurement.
Stopping point	Peak torque may occur before or at final seating.	Record seating behavior and whether the implant was reversed or advanced again.
Units and limits	Different systems report or cap torque differently.	Record the system, instrument and maximum displayed value.
Repeated manipulation	Back-and-forth movement can alter the interface.	Avoid unnecessary cycling and document corrective maneuvers.
RFA direction	ISQ varies with transducer orientation and surrounding geometry.	Measure in consistent directions and repeat when values are unexpected.

Useful operative record

- Implant system, macrogeometry, dimensions and placement position.
- Drilling sequence and any underpreparation, tapping or crestal widening.
- Peak insertion torque and whether a limit was reached.
- RFA or other stability measures, including measurement direction.
- Loading decision and the mechanical or biological rationale.

Documentation adds meaning: torque without implant design, osteotomy and loading context is difficult to interpret retrospectively.

High torque: clinical evidence and biological concern

Systematic reviews comparing high and lower insertion torque have not demonstrated a consistent difference in implant survival, marginal bone loss or overall complications. Many included studies were heterogeneous and used different definitions, implant designs and loading protocols. This evidence does not prove that unlimited compression is harmless.

Evidence layer	What it suggests	What it cannot prove
Clinical meta-analyses	High torque groups often show survival and marginal bone outcomes similar to lower torque groups.	Safety of every torque value, implant design or cortical condition.
Animal histology	Dense cortical bone can remodel successfully after high-torque placement in selected models.	Equivalent response in all human sites and medically complex patients.
Finite element studies	Higher interference can increase local strain and stress.	Direct clinical necrosis or peri-implantitis from a model alone.
Surface studies	Insertion can damage thread surfaces and release titanium particles, especially under high resistance.	A causal pathway from placement particles to clinical peri-implant disease.
Case-level observations	Pain or early crestal change can follow mechanically demanding placement.	That torque was the sole cause without excluding heat, position, infection or nerve injury.

No universal upper threshold

Values such as 50, 65 or 75 Ncm are used in studies, but they are research categories or system-specific references rather than a universal biological boundary. Manufacturer limits, implant macrogeometry and site anatomy must guide interpretation.

Balanced conclusion: high torque is not automatically harmful, but an unexpectedly high value is a signal to reassess cortical compression, implant seating and the loading plan.

Compression, microdamage and heat

Implant placement creates controlled bone injury. Osteocytes, microvasculature and the mineralized matrix must remain viable enough to support repair. Compression, microcracks and thermal injury arise through different mechanisms and should not be conflated.

Mechanism	How it arises	Risk reduction
Cortical compression	Large implant-osteotomy interference in a thick or narrow cortical compartment.	Use site-appropriate crestal preparation, tapping or implant geometry.
Trabecular compaction	Threads displace and compress cancellous bone.	Balance engagement with preservation of spaces and perfusion.
Microdamage	Drilling, self-cutting threads and local strain create microscopic cracks.	Use sharp instruments, controlled technique and a validated preparation sequence.
Thermal injury	Heat from drilling increases when irrigation, drill condition or technique is inadequate.	Maintain effective irrigation, intermittent drilling and appropriate speed.
Crestal strain	Coronal thread engagement concentrates force near the marginal cortex.	Assess ridge width and avoid forcing an oversized or underprepared osteotomy.
Particle release	Friction and surface damage can detach titanium or coating fragments.	Avoid unnecessary insertion-removal cycles and excessive resistance.

Titanium particles are a plausible cofactor

Experimental studies confirm that particles can be released during insertion and localize near thread crests. In vitro work shows inflammatory potential under some conditions. Human evidence does not establish that placement-derived particles independently cause peri-implantitis or marginal bone loss.

Pressure necrosis is not diagnosed by torque alone

A high displayed value cannot show cellular viability. Clinical concern increases when high resistance coincides with a narrow ridge, thick cortex, prolonged placement, overheating, unexpected pain or early crestal change.

Mechanistic caution: biomechanical plausibility should guide prevention and surveillance, but it should not be presented as proven clinical causation.

Low torque and micromotion

Low insertion torque can reflect a wide osteotomy, sparse trabeculation, limited cortical engagement or an implant design that generates little rotational friction. It does not always mean failure, but it narrows the margin for uncontrolled loading.

Finding	Interpretation	Possible response
Low torque with high ISQ	Rotational resistance is limited while lateral stiffness remains acceptable.	Interpret the site and prosthetic plan before deciding on loading.
Low torque with low ISQ	Primary stability is limited across two measures.	Use submerged or protected healing and avoid immediate functional loading.
Stable implant in a soft site	Macrogeometry or bicortical engagement may provide adequate fixation.	Protect from excessive micromotion and review healing.
Rotation at final seating	Interface fixation is inadequate.	Reassess implant dimensions, site, grafting and whether replacement is appropriate.
Unexpected fall in resistance	Possible cortical perforation, overpreparation or loss of engagement.	Stop, verify position and avoid advancing blindly.

Micromotion is load-dependent

The implant can be stable under gentle testing yet experience damaging movement under an immediate restoration. Prosthesis design, implant distribution, splinting, occlusal contacts and parafunction determine how external load reaches the interface.

Low thresholds are not absolute

Studies of immediate loading frequently use insertion torque in the range of 30 to 45 Ncm and ISQ values around 60 to 71, but protocols differ. Some selected implants succeed below these values. Thresholds should be treated as protocol criteria, not universal guarantees.

Loading decision: a low value calls for protection and reassessment, not automatic explantation. Stability measures must be interpreted with the restoration and the entire implant distribution.

Site-specific osteotomy adaptation

The osteotomy should match local architecture and the implant system. Adaptation aims to create secure engagement without excessive heat, compression or loss of cortical support.

Site pattern	Preparation concept	Main hazard
Thick dense cortex	Complete drilling sequence, possible crestal widening or tapping as specified by the system.	Overcompression, heat and difficult seating.
Thin cortex with dense trabeculae	Standard preparation with attention to cortical integrity.	Plate fracture or fenestration from malposition.
Thin cortex with sparse trabeculae	System-specific underpreparation or osteotome concept where appropriate.	Excessive undersizing can still damage a thin plate.
Narrow ridge	Prosthetically driven position, adequate bone envelope and consideration of augmentation or smaller dimensions.	Lateral pressure, dehiscence and compromised soft-tissue contour.
Extraction socket	Engage native apical or palatal bone while respecting socket anatomy.	False confidence from coronal gap or limited circumferential contact.
Augmented site	Confirm maturation and use a controlled preparation suited to graft composition.	Assuming radiographic density equals mature vital bone.

Crestal overdrilling has a specific purpose

Coronal widening can reduce cortical interference and peak torque in dense sites. It should follow implant-system guidance because excessive widening can sacrifice stability. The indication comes from the planned implant, ridge form and observed resistance, not from a routine rule.

Reverse torque or implant removal

When seating requires force beyond the instrument or system limit, forcing the implant can damage the connection, driver and bone. Controlled reversal, further osteotomy preparation and reinsertion may be safer, but repeated manipulation can also disturb the interface and release particles.

Surgical objective: create stable engagement with the least avoidable injury. Maximum compression is not the endpoint.

Loading, postoperative pain and review

Decision domain	Questions	Clinical consequence
Primary stability	Are torque, ISQ and clinical fixation consistent?	Determines whether immediate, early or conventional loading is mechanically plausible.
Implant distribution	Is load shared across adequate number, position and length of implants?	A splinted full-arch plan differs from a single crown.
Restoration	Can contacts, cantilever and provisional rigidity be controlled?	Poor load control can defeat apparently adequate stability.
Patient loading	Bruxism, parafunction or inability to follow diet restrictions?	May favor delayed loading or additional protection.
Biological context	Grafting, thin plates, systemic disease or impaired healing?	Can justify a longer protected phase despite high torque.
Surgical events	Overheating, cortical fracture, difficult seating or repeated manipulation?	Require documentation, review and possibly delayed loading.

Pain deserves a differential diagnosis

- Expected postoperative pain should improve over time and respond to routine management.
- Severe, increasing or disproportionate pain requires examination and review of implant position.
- Altered sensation requires prompt assessment of the mandibular canal or other neural structures.
- Persistent pain without suppuration can reflect mechanical compression, adjacent-tooth disease, neuropathic pain or another diagnosis.
- Do not label pain as pressure necrosis, material reaction or peri-implantitis without supporting evidence.

Follow the trajectory, not only the day-one value

Early review should consider wound healing, pain, mobility and restoration control. Serial RFA may be useful when measured consistently, but small changes should be interpreted within device repeatability and the biological healing timeline.

Safety net: high torque does not justify immediate loading by itself, and delayed loading does not correct an injured or malpositioned implant.

Clinical synthesis and selected references

Clinical synthesis

- Treat insertion torque as rotational resistance, not a direct measurement of osseointegration.
- Use RFA and clinical fixation as complementary information because they measure different properties.
- Interpret torque within implant design, osteotomy, cortical thickness and trabecular architecture.
- Record the preparation sequence, peak torque, measurement method and loading rationale.
- Recognize that clinical meta-analyses have not shown a consistent penalty from high torque.
- Avoid assuming that the absence of an average clinical effect makes unlimited compression safe.
- Do not apply one universal upper torque threshold across implant systems and sites.
- Use crestal widening or tapping selectively in dense cortex according to system guidance.
- Protect low-stability implants from uncontrolled micromotion rather than relying on torque alone.
- Present titanium particle release as an experimental cofactor, not a proven cause of peri-implantitis.

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Educational use and limitations

This material supports implant planning, operative documentation and loading decisions. It does not replace implant-system instructions, calibrated equipment, surgical training or individualized clinical judgment.

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