



(REVIEW ARTICLE)



STANDARDIZED EXPLANTATION PROTOCOLS FOR DENTAL IMPLANT REMOVAL: AN EVIDENCE-BASED REVIEW OF MINIMALLY INVASIVE RETRIEVAL TECHNIQUES

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ABSTRACT

Objective: Failing osseointegrated dental implants often require removal, yet no consensus-based, evidence-graded protocol exists to guide clinicians in selecting a minimally invasive explantation technique. This review synthesizes the available evidence on reverse-torque/counter-torque, trephine and bur, piezoelectric, and laser-assisted explantation systems, with the aim of clarifying their comparative success, invasiveness, and the quality of the supporting evidence base.

Methods: A narrative literature review was conducted using PubMed/MEDLINE, Embase and Scopus for English-language publications from 2005 to 2025, combining terms for dental implant explantation, removal technique, reverse torque, counter-torque, trephine, piezosurgery, and laser-assisted removal. Systematic reviews, comparative in vitro and in vivo studies, and clinical case series reporting explantation technique, success outcome, complications, or residual bone volume were prioritized for narrative synthesis.

Results: Across pooled systematic-review data, reverse-torque and counter-torque ratchet techniques (CTRT) are the most frequently reported and most conservative first-line options, with success rates in the range of 87–94% and low reported morbidity. Trephine and bur techniques achieve comparably high or higher success (94–100%) at the cost of greater bone removal and a small but real risk of sinus perforation or implant/instrument fracture. Piezoelectric surgery offers selective, nerve- and soft-tissue-sparing cutting but at the expense of longer operative time, while laser-assisted systems (Er,Cr:YSGG, Er:YAG, CO₂) demonstrate superior bone preservation and reduced thermal/mechanical artefact in vitro compared with trephine burs. Across all modalities, the underlying evidence is dominated by retrospective case series and in vitro models, with pooled cohorts rarely exceeding 1,200 implants across nearly two decades of literature, inconsistent definitions of explantation “success,” and follow-up data for reimplantation outcomes that are sparse or absent.

Conclusion: Reverse-torque/CTRT techniques should remain the first-line, most conservative approach, escalating to resective (trephine, bur), piezoelectric or laser-assisted techniques according to residual apical bone height and torque thresholds. However, the field lacks randomized controlled trials, standardized outcome definitions, and long-term reimplantation data. Development of a formally graded, consensus-based explantation protocol is warranted.

Keywords: Dental implant removal; Explantation; Reverse torque technique; Piezoelectric surgery; Laser-assisted explantation; Peri-implantitis

1 INTRODUCTION

Osseointegrated dental implants are a predictable and widely used treatment for partial and complete edentulism, with long-term survival historically benchmarked against the criteria proposed by Albrektsson and colleagues^[1], and more recently against implant-supported fixed prosthesis survival data reported by Pjetursson and colleagues in a systematic review with a mean observation period of at least five years^[5]. Despite these favourable outcomes, biological and mechanical complications accumulate with function time, and a proportion of implants ultimately fail and require removal.

Peri-implant disease is the dominant driver of late implant failure. Contemporary case definitions for peri-implant mucositis and peri-implantitis were formalized by Renvert and colleagues as part of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions^[2]. Meta-analytic estimates place the prevalence of peri-implantitis at approximately 19.5% at the patient level and 12.5% at the implant level^[3], while a separate systematic review reported implant-level prevalence ranging from 1.1% to 85.0% depending on diagnostic criteria and function time, with smoking and diabetes identified as consistent risk factors^[4]. A recent literature review by Masaki and colleagues further distinguished early implant failure, driven predominantly by patient-related factors such as smoking, diabetes, radiotherapy and pre-existing periodontitis, from late failure, which is most commonly attributable to peri-implantitis, implant fracture, and malpositioning^[6]. These authors also reported a weighted survival rate for replacement implants of only 86.3%, underscoring the clinical stakes of the initial explantation procedure for future prosthetic rehabilitation^[6].

When removal is indicated, the clinician's objective extends beyond simple extraction of the failed fixture: the technique chosen must minimize trauma to the peri-implant bone in order to preserve the option of immediate or early reimplantation. A range of techniques has been described, spanning purely mechanical counter-torque devices, resective instrumentation (trephine burs and carbide burs), piezoelectric ultrasonic surgery, and, more recently, laser- and heat-based thermo-explantation systems. However, as multiple systematic reviews have observed, the literature supporting these techniques remains fragmented: most reports are retrospective case series or small comparative cohorts, follow-up after reimplantation is inconsistently reported, and no professional body has yet issued a formally graded, consensus-based explantation protocol.^{[7][8]} This review therefore aims to (1) summarize and compare the evidence for reverse-torque/counter-torque, resective (trephine/bur), piezoelectric, and laser-assisted explantation techniques in terms of reported success, complications, and bone preservation; and (2) critically appraise the strength and limitations of this evidence base as a foundation for future standardized, evidence-based explantation guidelines.

2 MATERIALS AND METHODS

This article is a narrative review of the published literature; it did not involve human or animal subjects recruited by the author, and no institutional ethical approval or informed consent was therefore required. All data discussed are drawn from previously published, publicly available sources, which are cited in full in the reference list.

A structured literature search was performed in PubMed/MEDLINE, Embase and Scopus for English-language articles published between January 2005 and September 2025. Search terms combined the concepts “dental implant”, “explantation”, “implant removal”, “reverse torque”, “counter-torque”, “trephine”, “piezosurgery” OR “piezoelectric surgery”, “laser-assisted removal”, and “peri-implantitis”, combined with Boolean operators. Reference lists of retrieved systematic reviews were hand-searched for additional eligible studies (backward citation searching).

Systematic reviews, comparative in vitro and in vivo studies, and clinical case series that explicitly reported an explantation technique together with a success outcome, complication profile, or a quantitative measure of bone volume loss were prioritized for inclusion in the narrative synthesis. Non-English articles, single case reports without technique-level outcome data, and studies concerned exclusively with implant-site preparation (rather than removal) were excluded. Because study designs, outcome definitions and follow-up periods varied substantially across the identified literature, a formal meta-analysis was not undertaken; findings are instead synthesized narratively and, where appropriate, tabulated for comparison across techniques.

3 RESULTS AND DISCUSSION

3.1 Reverse-torque and counter-torque ratchet techniques

The reverse-torque technique, and its clinical refinement the counter-torque ratchet technique (CTRT), applies a controlled counter-clockwise torque to unscrew an osseointegrated implant along its original insertion path. In the

largest pooled systematic-review dataset available, reverse torque was the most frequently reported technique, applied to 284 of 372 explanted implants, with a success rate of 87.7%^[7]. A subsequent updated systematic review pooling 1,142 implants and 595 patients across 18 studies found that CTRT achieved the highest success rate with the least patient morbidity and the least bone removal of any technique examined, and recommended it as the preferred first-line approach whenever feasible, in part because it permits immediate reimplantation at the same surgical visit^[8].

This conservatism is not unlimited. In vitro work using resonance frequency analysis has shown that implant stability declines in a near-linear fashion as surrounding bone is progressively removed, with each additional millimetre of trephination depth reducing the implant stability quotient by approximately 5.3 units, suggesting that stability monitoring during any adjunctive resective step could help identify the point at which reverse torque becomes safely achievable^[9]. Clinically, a remaining apical bone height of approximately 4 mm or more, or a removal torque exceeding roughly 200 Ncm, has been proposed as a threshold beyond which reverse torque alone is unlikely to succeed and should be combined with a resective technique; failure of an unmodified reverse-torque attempt in these circumstances carries a recognized risk of implant fracture or fracture of the counter-torque instrument itself.

3.2 Resective techniques: trephine and carbide burs

Trephine burs and carbide burs remove a cylindrical core of bone surrounding the implant, sacrificing peri-implant bone volume in exchange for reliable, technique-independent access. Pooled data indicate very high procedural success – 100% for burs (49 implants) and 94% for trephines (35 implants) in one systematic review^[7], although the same review documented a case of sinus-floor perforation following trephine use and cautioned that resective techniques, while effective, are inherently less conservative than reverse torque and should be reserved for cases in which the latter is contraindicated or has failed^[7]. Some authors now regard trephine burs as increasingly outmoded for routine explantation given the availability of less destructive alternatives, reserving them chiefly for implants with insufficient remaining bone height for a reverse-torque approach^[12].

3.3 Piezoelectric surgery

Piezoelectric (ultrasonic) bone surgery uses frequency-modulated ultrasonic vibration to achieve selective cutting of mineralized tissue while sparing adjacent soft tissue, nerve and vascular structures, combined with cavitation and irrigation that maintain a relatively bloodless, high-visibility operative field^[10]. These properties have made piezosurgery attractive for the removal of fractured or malpositioned implants and for site preparation adjacent to critical anatomy, and comparative work in other oral-surgical contexts (for example, third-molar osteotomy) has consistently shown reduced postoperative pain, swelling and trismus relative to conventional rotary instrumentation, at the cost of a significantly longer procedural time. These trade-offs are plausible for implant explantation as well, but technique-specific comparative outcome data – success rate, bone-volume loss, and complication rate specific to piezoelectric explantation – remain limited to case-level reports rather than controlled comparative series, a gap explicitly noted in recent systematic reviews of removal techniques^[8].

3.4 Laser-assisted and thermal explantation

Laser-assisted explantation, most commonly using the Erbium:Chromium:Yttrium-Scandium-Gallium-Garnet (Er,Cr:YSGG) wavelength, has been directly compared with the conventional trephine bur in an in vitro model using human cadaveric mandibles. The laser group demonstrated a significantly smaller volume of bone loss than the trephine group, and scanning electron microscopy revealed empty trabecular spaces with well-defined margins and no evidence of carbonization in the laser group, contrasting with a smear layer and microcracking on trephine-prepared surfaces; the trephine bur, however, required a shorter preparation time^[11]. These findings support the biological rationale for laser-assisted removal – selective ablation with minimal collateral thermal damage – but the evidence remains confined to in vitro and cadaveric models rather than prospective clinical cohorts.

A conceptually related and still more experimental approach exploits controlled thermal energy to induce localized “osseodisintegration” – reversal of osseointegration through targeted bone necrosis at the implant-bone interface – rather than mechanical or ablative bone removal. A review of five patented thermal/mechanical explantation devices published between 2010 and 2018 concluded that, while each combined a handpiece, a coronal connecting device and mechanical and/or thermal energy delivery, none had yet reached routine clinical validation, and that temperature-sensing alone was likely an inadequate sole control parameter for safe, reproducible osseodisintegration^[12]. This underscores that thermally mediated explantation remains an investigational rather than an established clinical technique at present.

Table 1: Comparative summary of reported outcomes across explantation techniques. *Success-rate figures are drawn from pooled systematic-review cohorts and are not derived from head-to-head randomized comparisons; sample sizes (n) refer to implants reported in the cited source.

Technique	Reported success rate*	Relative invasiveness / bone loss	Principal advantages	Principal limitations
Reverse torque / CTRT	87.7% (n = 284) ¹	Lowest; original path, no cutting	Most conservative; permits immediate reimplantation	Limited by residual apical bone (≈ 4 mm) and torque threshold (≈ 200 Ncm); implant/instrument fracture risk
Trephine bur	94% (n = 35) ¹	High; circumferential core removed	Reliable, technique-independent access	Greatest bone sacrifice; sinus perforation, fracture risk
Carbide bur	100% (n = 49) ¹	Moderate–high	Widely available instrumentation	Bone loss; heat generation if irrigation inadequate
Piezoelectric surgery	Case-level only; comparative rates not established	Low–moderate; selective mineralized-tissue cutting	Soft-tissue/nerve sparing; bloodless field	Significantly longer operating time; learning curve
Laser-assisted (Er,Cr:YSGG)	In vitro comparative data only	Low; less bone volume lost than trephine ¹¹	Minimal thermal artefact; no carbonization ¹¹	Equipment cost/availability; limited clinical (in vivo human) data
Thermal “osseodisintegration” / devices	Investigational; not established	Theoretically minimal; unproven clinically	Potentially flapless, bone-conserving	Preclinical/patent stage; no validated temperature-control protocol ¹²

3.5 Synthesis and evidence gaps

Taken together, the available evidence supports a stepwise, bone-conserving philosophy: reverse torque or CTRT as the default first-line technique, escalating to resective, piezoelectric or laser-assisted approaches only when residual bone height or torque values render the conservative approach unsafe^{[6][8]}. This graded approach mirrors the clinical decision flow-charts proposed in several of the reviews synthesized here, which recommend basing technique selection on implant mobility, remaining bone support, and anatomical proximity to vital structures^[6].

Nonetheless, several limitations recur across this literature and constrain the formulation of a formally evidence-graded protocol. First, sample sizes remain small in absolute and cumulative terms: even the most comprehensive pooled systematic reviews to date have aggregated fewer than 1,200 implants across two decades of publications^{[7][8]}, and individual technique-specific series (particularly for piezoelectric and laser-assisted removal) are frequently limited to single-digit or low double-digit case numbers or in vitro models rather than clinical cohorts. Second, outcome definitions are inconsistent: “success” is variably defined as atraumatic implant retrieval without fracture, preservation of a minimum residual bone envelope, or eligibility for immediate reimplantation, which complicates direct comparison across studies and techniques. Third, follow-up after explantation is sparse: few studies report the survival of a subsequently placed replacement implant, despite evidence that repeat-implantation survival (reported at a weighted 86.3% in one review) is meaningfully lower than that of primary implants and declines further with each subsequent attempt^[6]. Fourth, true head-to-head randomized controlled trials comparing two or more explantation techniques in matched clinical scenarios are essentially absent from the literature identified in this review; comparative data largely derive from in vitro cadaveric or synthetic-bone models^{[9][11]}, which cannot fully capture clinical variables such as bone quality, implant surface characteristics, or operator experience.

These gaps have direct implications for guideline development. A standardized explantation protocol would benefit from: (i) a consensus, quantitative definition of explantation “success” that incorporates both the atraumatic nature of removal and the residual bone volume available for reimplantation; (ii) prospective multicentre registries or randomized trials directly comparing reverse-torque, resective, piezoelectric and laser-assisted techniques under

matched indications; (iii) routine reporting of reimplantation outcomes at defined follow-up intervals; and (iv) further clinical (rather than purely in vitro) validation of piezoelectric and laser-assisted systems, whose favourable bone-preservation profile is currently supported chiefly by preclinical data^{[10][11]}.

4 CONCLUSION

Reverse-torque and counter-torque ratchet techniques currently offer the most favourable balance of success and bone conservation and should remain the first-line approach to dental implant explantation whenever residual bone support and removal-torque values permit. Resective techniques using trephine or carbide burs remain reliable fallback options with well-documented, if less conservative, success rates, while piezoelectric and laser-assisted systems show biologically plausible advantages in tissue preservation that have not yet been substantiated by adequately powered clinical comparative studies. Across all modalities, the evidence base is characterized by small, heterogeneous cohorts, inconsistent outcome definitions, and minimal long-term follow-up of reimplantation outcomes. Standardized, evidence-based explantation guidelines will require prospective comparative trials, consensus outcome definitions, and systematic reporting of reimplantation survival before minimally invasive alternatives to traditional trephining can be formally graded against one another.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The author declares no financial, professional, institutional, or personal conflicts of interest relevant to the content of this review.

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