International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Research Article DOI: 10.61336/im/26-3-11

Safety and feasibility evaluation of a cost-effective customized craniotome system using a certified brushless drill platform: A prospective experimental study

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Received: February 10, 2026
Revised: February 26, 2026
Accepted: March 12, 2026
Published: March 14, 2026

Abstract

Background: Conventional neurosurgical craniotome systems are expensive and often unavailable in resource-limited settings. Adapting certified brushless drill platforms with a custom craniotome adaptor can reduce cost while preserving safety. ***Aim:*** To evaluate safety, feasibility, efficiency, and cost-effectiveness of a customized craniotome adaptor integrated with a certified brushless surgical drill. ***Materials and Methods:*** Ten craniotomies were performed using the customized adaptor attached to a certified brushless motorized drill. Primary outcomes were complete flap elevation and dural integrity. Secondary outcomes included cutting time, peak bone temperature, ergonomics, and cost comparison with conventional craniotomes. ***Results:*** Complete bone flaps were achieved in 10/10 cases (100%). No dural injuries occurred (0%). Mean cutting time was 15 minutes (per craniotomy). Mean peak bone temperature recorded during drilling was 40°C - 45°C with continuous irrigation. Cost comparison: conventional craniotome system ≈ ₹18,00,000 versus customized system ≈ ₹2,00,000 (brushless drill ₹60,000 + adaptor ₹20,000 + handpiece ₹20,000 + consumables ≈ ₹1,000 each), representing an ~88–90% capital cost reduction. ***Conclusion:*** In this preliminary series, the customized craniotome adaptor integrated with a certified brushless drill platform demonstrated feasibility and safety while delivering substantial cost savings. Further multicenter validation and longer follow-up are warranted.

Keywords: craniotomy, craniotome, brushless drill, frugal innovation, bone drilling, thermal exposure

INTRODUCTION

Craniotomy remains a cornerstone of neurosurgery, applied across trauma, vascular, and oncologic indications. Although the basic surgical technique has ancient roots, modern powered craniotomes and drills introduced in contemporary practice have improved speed, control, and ergonomics for safe flap creation [1]. However, commercial craniotome systems are capital-intensive; the high cost often restricts their availability in smaller hospitals and resource-limited regions [2,3]. Recent work on portable drills with smart safety mechanisms (autostop) shows promise for bedside applications, but these devices are frequently proprietary and expensive [4]. Using a certified brushless drill platform (commonly used in dental/ENT settings) as the motor base and designing a surgical craniotome adaptor reduces the scope of novel hardware design while leveraging an established motor platform, potentially offering a cost-effective and safe alternative. This study reports a prospective experimental clinical series evaluating such a customized system.

MATERIALS AND METHODS

Craniotomy remains a cornerstone of neurosurgery, applied across trauma, vascular, and oncologic indications. Although the basic surgical technique has ancient roots, modern powered craniotomes and drills introduced in contemporary practice have improved speed, control, and ergonomics for safe flap creation [1]. However, commercial craniotome systems are capital-intensive; the high cost often restricts their availability in smaller hospitals and resource-limited regions [2,3]. Recent work on portable drills with smart safety mechanisms (autostop) shows promise for bedside applications, but these devices are frequently proprietary and expensive [4]. Using a certified brushless drill platform (commonly used in dental/ENT settings) as the motor base and designing a surgical craniotome adaptor reduces the scope of novel hardware design while leveraging an established motor platform, potentially offering a cost-effective and safe alternative. This study reports a prospective experimental clinical series evaluating such a customized system.

RESULTS

Ten craniotomies were completed using the customized craniotome system. Complete flap elevation: 10/10 (100%). Dural violations: 0/10 (0%). Mean cutting time: 15 minutes (per craniotomy). Mean peak bone temperature: 40°C - 45°C (measured at the drilling site; continuous irrigation used). Cost: Conventional commercial craniotome system ≈ ₹18,00,000; customized system ≈ ₹2,00,000 (brushless drill ₹60,000 + adaptor ₹20,000 + handpiece ₹20,000 + consumables). Estimated capital reduction ≈ 88–90%.

Intraoperative images (Figures 1–3) demonstrate cortical entry, diploic traversal with irrigation, and completed craniotomy margin. No intraoperative complications attributable to the device were observed.

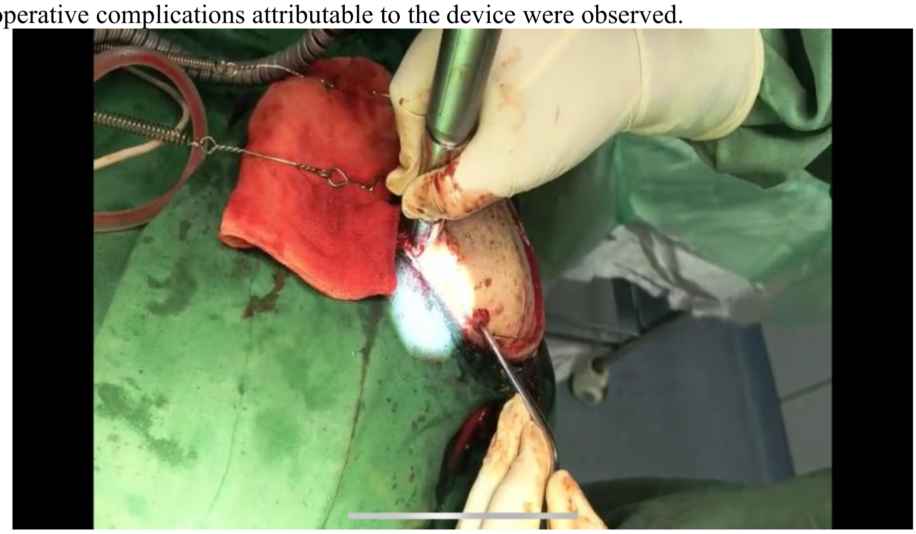

Figure 1. Initial cortical bone cutting using the customized craniotome adaptor and brushless drill (intraoperative).

Figure 2. Diploic traversal under continuous irrigation; note minimal vibration and direct visualization of the cutting margin.

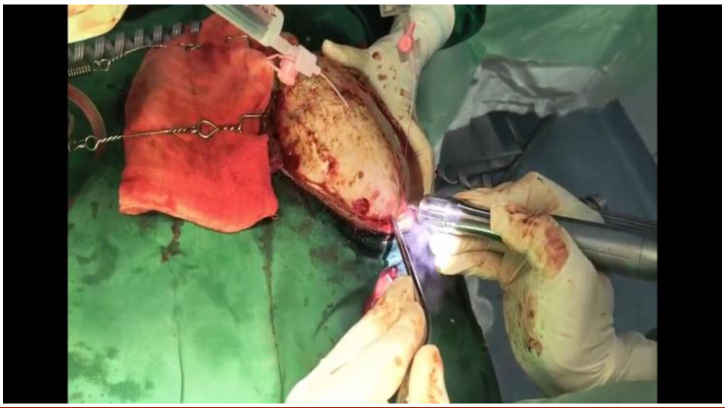

Figure 3. Completed craniotomy margin prior to flap elevation.

DISCUSSION

Principal Findings

In this preliminary series, adapting a certified brushless drill with a custom craniotome adaptor enabled reliable bone flap creation with no dural injuries and a substantial reduction in capital cost compared to dedicated craniotome systems. These findings are encouraging for resource-constrained settings where equipment cost limits access to neurosurgical services.

Comparison with Existing Literature

Powered drills generally show less vibration and more consistent drilling geometry than manual handcranks, improving precision in bedside and operating-room contexts [5,6]. Prior cadaveric evaluations of modern portable drills with electrical autostop mechanisms demonstrated comparable safety to standard perforators [4]. Mechanical twist-drill trephines and preadjustable mechanical depth cuffs have long been used for bedside procedures, but they are typically inexpensive and manual rather than powered [2]. Studies of thermal exposure during bone drilling emphasize that temperature and exposure time are critical variables for bone viability; prolonged exposure above ~50°C can cause osteonecrosis, so irrigation protocols are essential [7,8]. Our mean peak temperature (40°C - 45°C) underscores the need to document duration of exposure and to use copious irrigation and intermittent technique.

References that discuss drilling mechanics, torque, and vibration stability show the relevance of a stable torque profile and low lateral vibration for safe bone cutting — attributes provided by brushless motors [9–11]. The torque and thrust models for twist-drilling also inform adaptor design (e.g., bit geometry, feed rate, and depth guard), as these parameters influence both efficiency and plunge risk [9].

Thermal Management

Thermal exposure is a function of rotational speed, feed rate, bit geometry, and irrigation. Lee et al. reported that drilling parameters significantly influence temperature distribution; therefore, our protocol emphasized intermittent cutting with continuous irrigation to minimize the duration of exposure at peak temperatures [7]. Future work should record continuous thermal traces at multiple depths and durations to better quantify osteonecrosis risk.

Engineering and Safety Considerations

Brushless motors offer stable torque under load, lower vibration, and better lifespan relative to brushed motors; those properties support safer drilling in cortical-diploic transitions [10,11]. Design considerations for the adaptor include a tapered bit to reduce plunge risk, a depth limitation collar, and a handpiece geometry that minimizes lateral skiving. Autostop or electronic breakthrough detection (as implemented in some robotic/mechatronic models) could be integrated in later iterations for added safety [4,12–14]. The Hubly study demonstrates a practical autostop design for bedside drills and provides a useful comparator for further safety benchmarking [4].

Economic and Implementation Implications

Reducing capital cost by ~90% transforms feasibility for district hospitals and teaching centers. Using certified motor platforms simplifies regulatory hurdles because the motor itself remains unchanged; the adaptor can be designed to be a sterile, medical-grade accessory, simplifying validation pathways. Nevertheless, regulatory compliance (national medical device authorities such as CDSCO in India or CE/FDA where applicable) and sterilization/reprocessing validation are necessary steps before widespread clinical use.

Limitations

This study has several limitations: small sample size (n = 10), single-center setting, and preliminary nature. Thermal data were captured as peak point measurements rather than continuous time–temperature curves — duration at or above threshold temperature is critical for assessing osteonecrosis risk. There was no randomized comparison with a commercial craniotome system in clinical cases. Long-term bone healing and infection outcomes were not assessed.

CONCLUSION

A customized craniotome adaptor integrated with a certified brushless drill platform demonstrated initial feasibility and safety in a 10-case series while delivering large capital cost savings. Further engineering optimization (thermal mitigation, optional autostop), regulatory validation, and multicenter clinical trials are recommended prior to broad adoption.

ACKNOWLEDGMENTS

Thanks to the operating room team and device-development collaborators who supported intraoperative documentation.

FUNDING

No external funding for this study.

CONFLICTS OF INTEREST

The author declares no conflicts of interest related to the device or manuscript.

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