Gamma Knife Immobilization: Development of an Add-On Brace to Improve Head Stability During Radiosurgery

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ABSTRACT

Purpose: To improve immobilization of Gamma Knife patients' heads by limiting pronation motion through dental fixation, thereby enabling shorter treatment times, more accurate dose delivery, and enhanced patient comfort.

Methods: A 3D-printed resin add-on brace was developed to augment the existing thermoplastic mask and optical monitoring system used during Gamma Knife treatments. It provides gentle, tolerable pressure against the upper lip and teeth to restrict pronation. The assembly includes three components: a base, joint, and mouthpiece (together with a metal insert). The current design improves upon an earlier version by adapting it into a practical device that accounts for space constraints within the Gamma Knife hemispherical treatment volume. Continuous contact with the Elekta's existing rigid frame further enhances stability. A modular mouthpiece library provides more flexibility to adapt to variations in the geometry of patients' heads, optimizing dental fixation, with central mouthpiece section rotates to adjust the fixation angle.

Results: Preliminary evaluations indicate improved stability. After intentional head movements, the patient's head equipped with the brace returned to the reference position more consistently and with smaller residual offsets compared with tests performed without the brace. Exceeding the 1.5 mm threshold was also more difficult and required deliberately large movements.

Conclusion: This add-on brace shows promise as a simple, effective enhancement to current mask-based immobilization for the Gamma Knife Icon, with potential to reduce treatment interruptions and improve comfort. Future work includes metal fabrication for greater stability, quantitative evaluation across additional simulated sessions, and development of a workflow for clinical implementation.

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INTRODUCTION

Gamma Knife (GK) Stereotactic Radiosurgery

- High-precision radiation for brain tumors, AVMs, neurological disorders.
- 192 Co-60 sources, 8 sectors, each with independent collimator (Fig.1).
- Automatic isocenter adjustment — no manual repositioning.

Patient Motion Management

- Infrared HD tracking (real time).
- MBPCC protocol: auto-pause if motion >1.5 mm.
- Ensures accuracy, but increase time and reduce comfort.
- Treatment time: 1–3 hours → strict immobility required.

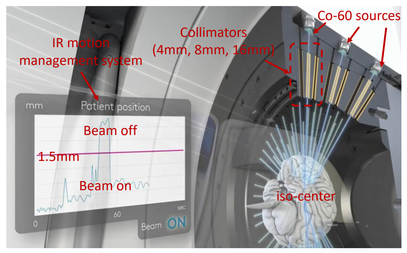


Fig. 1 Elekta Icon GK system[2]

Immobilization at MPBCC

- Patient-specific thermoplastic mask + Molded thermoplastic-metal mouthpiece.
- Applies pressure to the upper lip to counteract pronation.
- Labor-intensive—each patient requires a uniquely sized mouthpiece.
- Still permits minor voluntary motion.

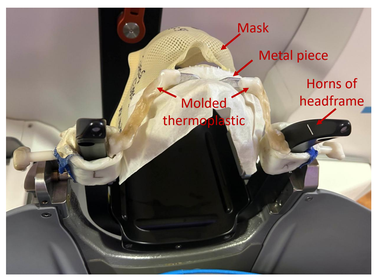


Fig. 2 Current immobilization at MBPCC

PREVIOUS DESIGN

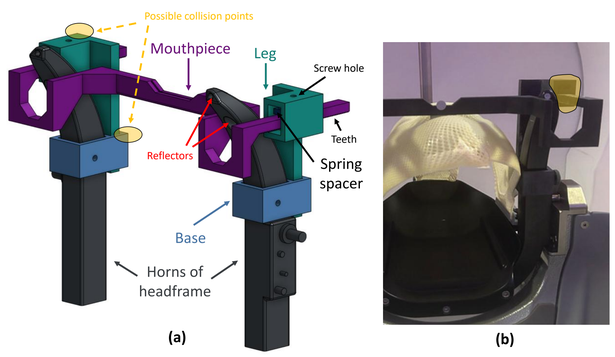


Fig. 3 Previous design.
(a) CAD assembly with possible collision points highlighted; (b) Printed prototype on mask

Custom add-on brace

- Base + Leg+ Mouthpiece + Spring spacer

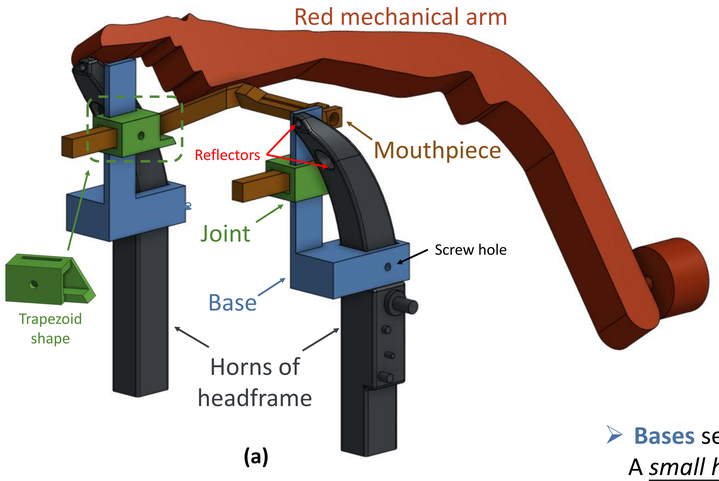
Problem

- Collision with GK inner hemisphere during treatment

Suspected reason

- Assembly extended too far beyond horns

NEW DESIGN



Prevent collision: Model for the most extreme case

When the *couch is at its limit position*, the positions of the horns were measured relative to **the fixed red mechanical arm** that defines the GK inner hemisphere. The overall structure was restricted to the *space within the horns* to avoid any potential collision.

Restrict head movement: Structure stability

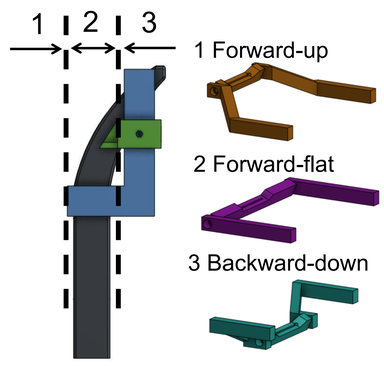
➢ **Bases** secured to the bottom of the horns.
A *small horizontal extension* enhances structural stability.

The vertical bar allows the mouthpiece to move up or down to accommodate different face heights, whose *height is designed to stay within the horn height* to prevent interference.

➢ **Joints** can attach at any point along the vertical bar, depending on patient anatomy.
Their *trapezoidal side* ensures constant contact with the horns, minimizing tilt and reducing patient motion.

➢ **Mouthpiece** is locked at its most stable position according to patient's face.
Two legs of the mouthpiece rest directly on the base bar, with *surface friction* preventing rotation.
The *central portion of the mouthpiece can rotate* to the optimal angle for dental fixation and is secured to the two legs with screws.

Mouthpiece library: Different facial dimensions



➢ **Mouthpiece** allows forward and backward adjustments.

Forward-up (FU), forward-flat (FF), and backward-down (BD) correspond to patients whose mouths are located at area 1, 2, and 3, respectively.

FU and BD provide additional height or depth adjustment if the vertical bar alone is insufficient. FU version has rounded corners to prevent collision. BD version can be used in reverse for mouths positioned horizontally beyond the horns.

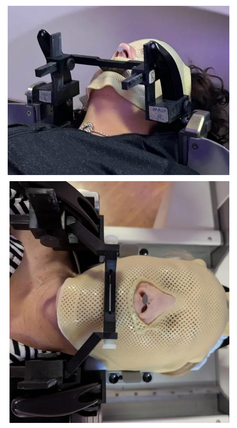


Fig. 4 New design.
(a) CAD assembly with red mechanical arm; (b) Mouthpiece library and their usage scenarios; (c) Printed prototype with mouthpiece FF (up) and FU (down) on mask.

RESULTS

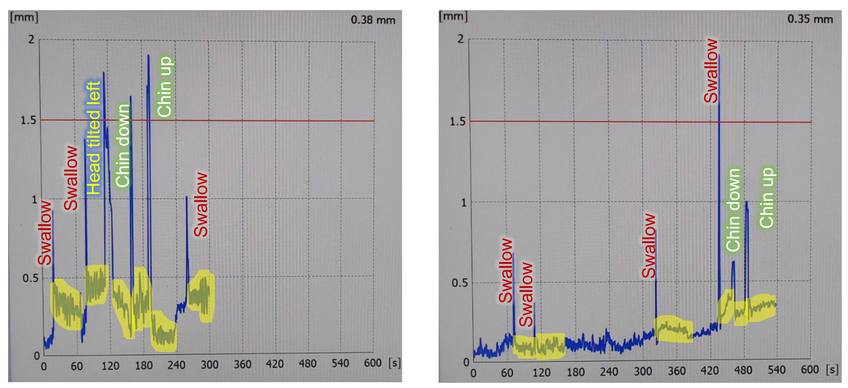


Fig. 5 Tracking of the nasal marker using the infrared high-definition motion management system.
(a)Without the brace; (b) With the brace

Improved stability with brace

- Back to reference position more consistently and with smaller residual offsets
- Exceeding the 1.5 mm threshold was also more difficult and required deliberately large movements

REFERENCES

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