Case Report

Surgical Application of a 3D-Printed Upper Beak Prosthesis in a Pacific parrotlet (*Forpus coelestis*): A Preliminary Case Report

Benchapol Lorsunyaluck[1,2] Anupong Enija[1] Phunyanuch Thamaratananon[1] Sarocha Amattat[1] Issariya Kajeerum[1] Sasiwimon Sae-lim[1] Supamard Sujatanond[3] Nijanan Siriarchawattana[1*]

[1]Panalai Veterinary Hospital, 100/5 M.5, Tiwanon Road, Pakkret, Pakkret district, Nonthaburi, 11120, Thailand
[2]Akkharatchakumari Veterinary College, 222 Thaiburi, Thasala district, Nakhonsithammarat, 80160, Thailand
[3]Department of Industrial Engineering, Faculty of Engineering, Thammasat School of Engineering Thammasat University, Klong Nueng, Klong Luang district, Pathumtani, 12120, Thailand

[*]Corresponding author, E-mail address: nijanan.sir@gmail.com

Received: 16 June 2025; Revised: 26 August 2025; Accepted: 27 August 2025

Abstract

Severe beak deformities or loss in psittacine birds significantly impair essential functions such as feeding, preening, and climbing. This case report presents the first documented surgical implantation of a 3D-printed upper beak prosthesis in a Pacific parrotlet (*Forpus coelestis*), a small parrot species that presents unique anatomical and mechanical challenges. The patient, a female parrotlet, had suffered complete upper beak loss following a traumatic injury. A patient-specific prosthetic beak was digitally designed based on computed tomography imaging of conspecific anatomy, then fabricated using stereolithography 3D printing and coated with dental composite resin to enhance biocompatibility and durability. Surgical fixation was achieved using a titanium orthodontic miniscrew, transcranial stainless steel wire, and composite resin sealing, with the procedure completed within approximately 15 minutes to minimize anesthetic risk. Postoperatively, the bird began eating soft food independently by day 3 and resumed functional behaviors including food manipulation and perching. Long-term monitoring revealed stable prosthesis integration for one year. At that point, granulation tissue developed at the interface, leading to gradual loosening and the elective removal of the prosthesis. This case highlights the feasibility and clinical potential of using 3D-printed prosthetics for beak reconstruction in small avian species. The approach provides a reproducible framework that can be adapted to both smaller and larger parrots, offering a valuable treatment option for traumatic beak loss across a range of bird species. It also underscores the role of digital fabrication in advancing avian reconstructive surgery and improving animal welfare.

Keywords: Beak prosthesis, 3D-printed, Implantation, Parrotlet, Rhinotheca

การผ่าตัดติดตั้งปากเทียมสามมิติบริเวณปากบนในนกฟอพัส (*Forpus coelestis*): รายงานเบื้องต้นของกรณีศึกษา

เบญจพล หล่อสัญญาลักษณ์[1,2] อนุพงศ์ อินิจจา[1] ปุณยนุช ธรรมรัตนนนท์[1] สโรชา อามาตรทัศน์[1]
อิสริยา ขจีรัมย์[1] ศศิวิมล แซ่ลิ่ม[1] สุภมาศ สุชาตานนท์[3] นิจนันท์ ศิริอาชาวัฒนา[1*]

[1]โรงพยาบาลสัตว์พนาลัย 100/5 หมู่ 5 ถนนติวานนท์ ตำบลปากเกร็ด อำเภอปากเกร็ด จังหวัดนนทบุรี 11120 ประเทศไทย
[2]วิทยาลัยสัตวแพทยศาสตร์อัครราชกุมารี 222 ตำบลไทยบุรี อำเภอท่าศาลา จังหวัดนครศรีธรรมราช 80160 ประเทศไทย
[3]ภาควิชาวิศวกรรมอุตสาหการ คณะวิศวกรรมศาสตร์ มหาวิทยาลัยธรรมศาสตร์ ตำบลคลองหนึ่ง แขวงคลองหลวง ปทุมธานี 12120 ประเทศไทย

[*]ผู้รับผิดชอบบทความ E-mail address: nijanan.sir@gmail.com

Received: 16 June 2025; Revised: 26 August 2025; Accepted: 27 August 2025

บทคัดย่อ

การเสียรูปหรือการสูญเสียปากในนกแก้ว ส่งผลกระทบอย่างรุนแรงต่อพฤติกรรมพื้นฐานที่จำเป็นต่อการดำรงชีวิต เช่น การกินอาหาร การดูแลตกแต่งขน และการป้องกันตัว รายงานฉบับนี้จึงนำเสนอกรณีศึกษาครั้งแรกของการผ่าตัดติดตั้งปากเทียมที่ผลิตด้วยเทคโนโลยีการพิมพ์สามมิติ (3D printing) บริเวณปากบนของนกแก้วสายพันธุ์แปซิฟิกพารอตเลต หรือนกฟอพัส (Pacific parrotlet; *Forpus coelestis*) ซึ่งเป็นนกแก้วขนาดเล็กที่มีข้อจำกัดทางกายวิภาคและกลไกเฉพาะตัว สัตว์ป่วยรายนี้เป็นนกฟอพัสเพศเมียที่ได้รับบาดเจ็บจากอุบัติเหตุโดนนกที่มีขนาดใหญ่กว่ากัด ส่งผลให้สูญเสียปากส่วนบนทั้งหมด การรักษาประกอบด้วยการออกแบบปากเทียมเฉพาะรายโดยอิงจากภาพถ่ายเอกซเรย์คอมพิวเตอร์ (Computerized tomography scan) ของนกสายพันธุ์เดียวกัน จากนั้นผลิตชิ้นงานด้วยเทคโนโลยีการพิมพ์สามมิติด้วยเทคนิคสเตอริโอลิโธกราฟี และเคลือบด้วยเรซินทางทันตกรรม เพื่อความเข้ากันได้ทางชีวภาพและความทนทานในการใช้งาน ขั้นตอนการผ่าตัดเริ่มจากการฝังสกรูไทเทเนียมขนาดเล็กบริเวณปากส่วนบนที่เหลือ ร้อยลวดสแตนเลสผ่านกะโหลก และยึดปากเทียมเข้ากับกะโหลกพร้อมปิดรอยต่อด้วยเรซินทันตกรรม โดยทั้งหมดใช้เวลาเพียงประมาณ 15 นาที ซึ่งช่วยลดความเสี่ยงจากการวางยาสลบที่มักพบในนกขนาดเล็ก ภายหลังการผ่าตัด นกเริ่มกินอาหารนิ่มได้ด้วยตนเองภายใน 3 วัน และกลับมาแสดงพฤติกรรมการใช้ปากตามธรรมชาติได้อย่างต่อเนื่อง จากการติดตามผล พบว่าปากเทียมสามารถคงสภาพและทำงานได้อย่างมีประสิทธิภาพเป็นระยะเวลาหนึ่งปี ก่อนที่จะเริ่มหลุดออกเนื่องจากมีเนื้อเยื่องอกทดแทน (Granulation tissue) ก่อตัวบริเวณจุดยึด จึงมีการถอดอุปกรณ์ออกเพื่อป้องกันภาวะแทรกซ้อนในอนาคต รายงานฉบับนี้สะท้อนให้เห็นถึงศักยภาพและความเป็นไปได้ทางคลินิกในการประยุกต์ใช้เทคโนโลยีการพิมพ์สามมิติเพื่อการบูรณะปากในนกขนาดเล็กได้อย่างมีประสิทธิภาพ อีกทั้งยังสามารถนำแนวทางนี้ไปพัฒนาและต่อยอดใช้กับสัตว์ปีกสายพันธุ์อื่นทั้งขนาดเล็กและใหญ่ได้ในอนาคต พร้อมทั้งชี้ให้เห็นถึงบทบาทของการผลิตแบบดิจิทัลในการยกระดับคุณภาพการรักษาด้านศัลยกรรมตกแต่งในสัตว์ และการส่งเสริมสวัสดิภาพสัตว์อย่างเป็นรูปธรรม

คำสำคัญ : ปากเทียม เทคโนโลยีการพิมพ์ 3 มิติ การฝังวัสดุฝังเทียม นกฟอพัส จงอยปากบน

Introduction

In recent years, the Pacific parrotlet (*Forpus coelestis*) has become one of the most popular small-sized companion parrot species, favored for its intelligence, manageable size, and engaging personality. As the human-animal bond deepens in modern households, birds are increasingly regarded as cherished family members rather than traditional pets. This shift has led to greater emotional investment and higher standards in veterinary care, especially when it comes to preserving the quality of life following traumatic injuries. Due to their small stature, Pacific parrotlets, commonly kept in captivity, are particularly susceptible to injuries when housed with larger birds. Beak trauma is a common problem in the companion parrot. Beak injury most often occurs secondary to bird bites, other forms of aggression, or predator bites (Emily and Eisner 2021). The bird's beak (rhamphotheca) consists of two primary components: the upper beak or rhinotheca, and the lower beak or gnathotheca (Figure 1). These keratinized structures overlay a bony core and are essential for a wide array of natural behaviors. The avian beak plays a critical role in feeding, preening, object manipulation, climbing, and even locomotion (Doneley 2021; Lessner et al., 2023; Dickinson et al., 2024). However, if more than two-thirds of the beak, especially near the base, is lost, the germinal epithelium responsible for keratin regeneration is usually damaged, resulting in permanent structural loss (Matta et al., 2022). In such cases, the bird may become unable to perform basic natural behaviors, posing serious welfare concerns (Tokita 2003).

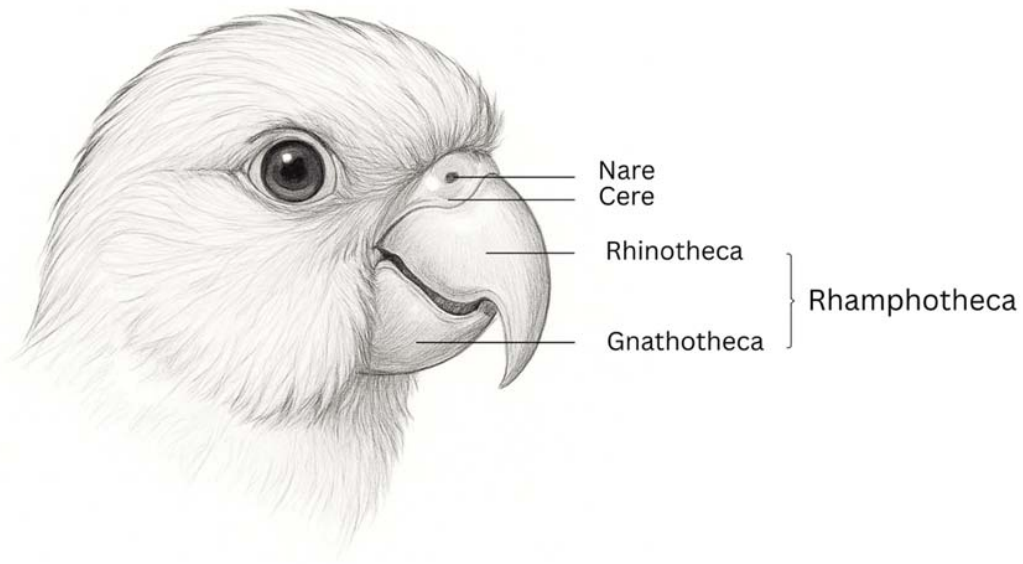


Figure 1. Anatomical illustration of the rhamphotheca in a Pacific parrotlet (*Forpus coelestis*).

Over the past decade, numerous prosthetic techniques have been developed to restore beak function in avian species. Materials used have ranged from dental acrylics, metal implants, toy plastic components, and 3D-printed constructs (Steenkamp 2014; Emily and Eisner 2021). In Amazon parrots (*Amazona oratrix*), cold-curing acrylic resin combined with improvised metal scaffolding has been successfully applied to restore rostral maxillary fractures, demonstrating functional recovery and structural integrity with long-term follow-up (Matta et al., 2022). Additionally, a report by Panelli Marchio et al. (2022) showed the successful application of acrylic prostheses in five species: a

roadside hawk (*Rupornis magnirostris*), a cockatiel (*Nymphicus hollandicus*), turquoise-fronted parrots (*Amazona aestiva*), and a maritaca (*Pionus maximiliani*). These birds received rhinothecal reconstructions using cold-curing acrylic resin and showed positive outcomes without complications during follow-up (Panelli Marchio et al., 2022). Furthermore, resourceful adaptations have been reported in smaller parrots. A green-cheek conure (*Pyrrhura molinae*) underwent remote-guided beak reconstruction using a prosthetic made from a plastic toy bird, demonstrating the feasibility of telemedicine-assisted avian surgery in low-resource environments (Patel 2021). In a great hornbill (*Buceros bicornis*), a 3D-printed prosthesis was designed and fitted to replace a damaged casque due to squamous cell carcinoma, marking a landmark application of additive manufacturing in avian craniofacial restoration (Xie et al., 2019). A similar technique was later used in an Oriental stork (*Ciconia boyciana*) with successful results (Kim et al., 2023). However, these cases have typically involved medium- to large-sized parrots, with no documented prosthetic application in the Pacific parrotlet, in which the small size presents unique anatomical and mechanical challenges. Prosthetic beak reconstruction in avian species involves multiple interdependent factors, including the prosthesis material, fixation technique, and postoperative care. Cold-curing acrylic resin offers the advantage of being lightweight and well-tolerated; however, it requires intraoperative sculpting, which may lengthen anesthesia time. Pre-formed components, such as those adapted from plastic toys, can reduce operative time and demonstrate creative adaptability, though achieving a precise anatomical fit and versatile fixation options may be challenging. Metal implants provide rigidity but may be limited by weight and installation space, particularly in small psittacine species. Advances in three-dimensional (3D) printing now allow for pre-fabricated, species-specific prostheses that combine weight optimization with tailored fixation designs, potentially reducing surgical time and improving functional outcomes. Such approaches build upon the strengths of previous techniques while addressing the anatomical and mechanical challenges unique to smaller birds, including the Pacific parrotlet.

In this case, a 3D-printed prosthesis for upper beak reconstruction was selected for its superior customizability, precision, biocompatibility, and lightweight properties (Shilo et al., 2018). The advent of 3D printing in veterinary medicine has revolutionized prosthetic development by enabling the creation of patient-specific devices with optimal anatomical conformity, enhanced structural integrity, and reduced fabrication time (Xie 2019; Kim et al., 2023). The ability to digitally scan, model, and produce a customized prosthesis allows for a more accurate fit and improved surgical outcomes, particularly in small avian patients where anatomical variation and size constraints present significant challenges. This report presents the first documented case of a 3D-printed upper beak prosthesis surgically affixed to a parrotlet with complete upper beak loss due to trauma. The objective is to demonstrate the feasibility of applying 3D-printed prosthetics to tiny avian species and to provide a clinical reference for future cases involving beak loss in miniature parrots.

Case description

Case background and clinical indication

A female Pacific parrotlet presented with complete upper beak loss due to a bite from another bird (Figure 2). The injury occurred on the same day, and the bird was brought in for evaluation immediately thereafter. On initial examination, the bird was unable to grasp or manipulate

food, and the beak injury appeared as an open wound with exposed soft tissue. The bird was treated with ceftiofur crystalline free acid (EXCEDE™, Zoetis LLC., U.S.A.) 50 mg/kg intramuscularly every 4 days, for 2 doses for infection control, and 1 dose of robenacoxib (Onsior™, Bela-Pharm GmbH & Co. KG, Vechta, Germany) 10 mg/kg intramuscularly for analgesia and anti-inflammatory support. Due to the bird's inability to feed independently, force feeding with a commercial hand-feeding formula was initiated using a syringe with a feeding tube to ensure adequate caloric intake during the recovery period. This supportive care helped stabilize the patient's body condition, prevent further metabolic decline, and wound contamination by food. Over the course of approximately one month, the wound underwent gradual epithelialization, with sloughing of necrotic tissue and the development of a healthy granulation bed, rendering the site suitable for prosthetic application. Given that the extent of the beak loss exceeded the regenerative capacity of the germinal epithelium, spontaneous regrowth was deemed impossible. Surgical implantation of the prosthesis was therefore planned and carried out approximately one month after the injury to restore prehension and improve long-term welfare.



Figure 2. Complete upper beak loss in a female Pacific parrotlet (*Forpus coelestis*) due to a traumatic injury.

Prosthesis design and fabrication

Anatomical references were obtained from a healthy Pacific parrotlet that had died of natural causes. Anatomical data were collected using the MyVet CTi3D computed tomography (CT) scanner, a cone-beam CT system tailored for veterinary use. It offers high-resolution 3D imaging with lower radiation doses and a fast scanning time, making it suitable for small exotic animals and reducing motion artifacts during imaging (MyVet Imaging 2025). The acquired stack of 2D DICOM CT images (Figure 3A)

was then imported into 3D Slicer (version 5.6.1), an open-source medical image processing platform. In this step, threshold-based segmentation and manual refinement were performed to isolate the beak and craniofacial structures from surrounding tissues. The software's volume rendering function was then used to reconstruct a high-resolution 3D anatomical model (Figure 3B), enabling precise visualization of the beak's morphology and dimensions. The segmented beak region from a morphologically intact specimen was exported in STL format and imported into Nomad Sculpt (version 2.2), a three-dimensional computer-aided design (CAD) application. Within Nomad, the intact beak was digitally separated from the head model to serve as a morphological reference template for the prosthetic design. This template was then adapted to incorporate features for a wiring attachment technique (Figure 3C), ensuring secure fixation. Using an anatomically accurate beak as the starting reference allowed the prosthesis to replicate the natural curvature, occlusion, and proportional dimensions of the original beak with high fidelity.

The prosthetic beak was fabricated using stereolithography (SLA) 3D printing with standard photopolymer resin. After printing, the beak was post-cured under ultraviolet (UV) light at 60°C for 30 minutes. To enhance mechanical durability and biocompatibility, the printed prosthesis was coated with a flowable dental composite resin. Examples of the 3D-printed prosthetic beaks are shown in Figure 4. This preoperative fabrication approach allows the prosthesis to be prepared in advance, significantly reducing operative time during surgery. As a result, it improves surgical efficiency and minimizes physical stress on the animal.

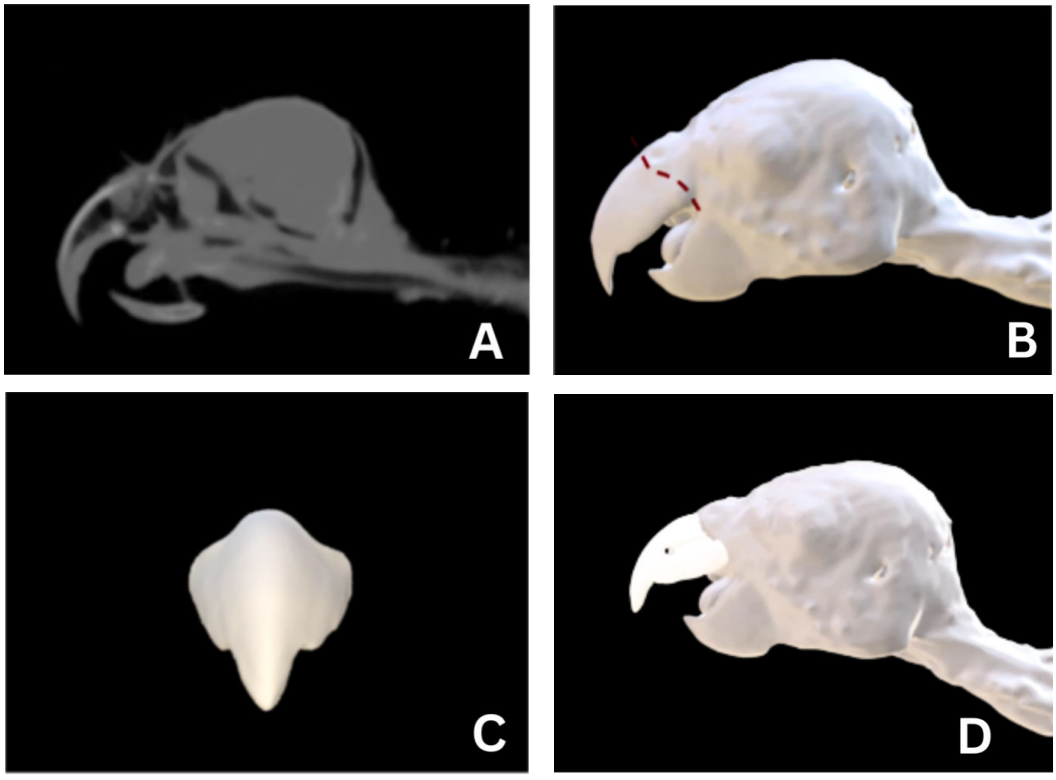


Figure 3. Workflow of prosthetic beak fabrication. (A) CT scanning of a Pacific parrotlet head using MyVet CTi3D. (B) 3D anatomical model reconstructed from CT images. The red dashed lines indicate the segmentation region. (C) Digital reconstruction of the beak geometry and (D) final prosthesis design showing attachment integration.

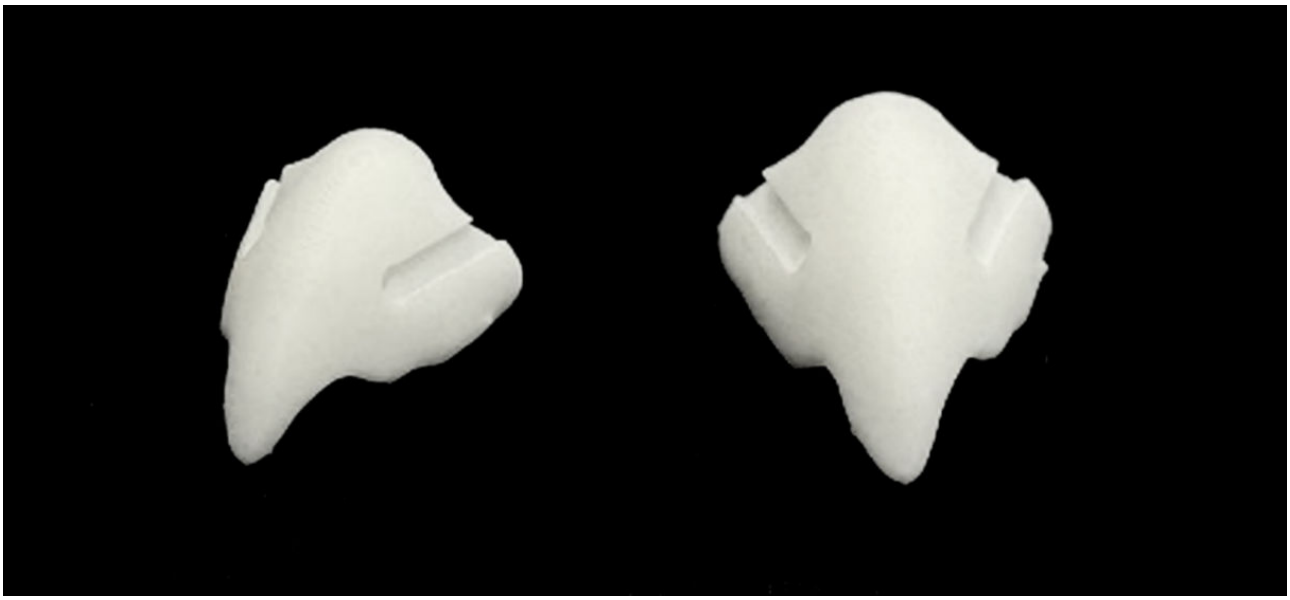


Figure 4. 3D-printed prosthetic beaks replicating natural morphology.

Surgical procedure and fixation technique

Prior to surgery, the patient underwent a thorough physical examination, with particular attention to the healing status of the soft tissue surrounding the cere and the rhinothecal implantation site. The area was assessed to ensure complete epithelialization and the absence of active inflammation or infection, both of which are prerequisites for prosthesis fixation. To minimize the risk of regurgitation under anesthesia or during restraint, food was withheld for approximately four hours preoperatively. Additionally, pre-oxygenation was performed to enhance oxygen reserves prior to induction.

The parrotlet was anesthetized via intramuscular injection into the pectoral muscle with midazolam (Midazolam-hameln®, Siam Bioscience Co. Ltd., Thailand) at a dose of 5 mg/kg and butorphanol (Butodol®, NEON LABORATORIES LTD., India) at a dose of 0.6 mg/kg intramuscularly, providing deep sedation and analgesia. After confirming the onset of anesthesia, the patient was stabilized for the procedure. Throughout the operation, the bird was gently restrained by a trained veterinary nurse to facilitate multi-angle manipulation of the head and beak. This hands-on technique was essential, as fixation of the prosthesis required access from multiple angles and could not be accomplished with the bird held in a single static position. If the lower beak was found to be overgrown, it was carefully trimmed to the appropriate length using a pliers-type nail clipper to achieve proper alignment with the upper beak, and the excised portion was discarded in a biohazard container.

The oral cavity and cere were then cleaned to remove mucus and debris. A disinfectant containing hypochlorous acid was applied to the surgical area to minimize infection risk (Figure 5). A dental orthodontic micro implant, specifically a self-tapping mini screw made of titanium alloy (1.4 x 6 mm) was inserted into the midline of the remaining rhinotheca to serve as a mechanical anchor for prosthetic fixation (Figure 6).

To secure the prosthetic beak, a 25G x 5/8" hypodermic needle was passed laterally through the cranial region from left to right, at a site midway between the medial canthus and the base of the rhinotheca. A 0.2 mm

stainless steel dental wire was threaded through the needle, which was then withdrawn, leaving the wire in place (Figure 7). The wire was guided through designated holes in the prosthetic beak, which was then positioned anatomically over the skull. The wire was twisted to secure the prosthesis tightly in place, trimmed, and its ends were bent and tucked into a recessed groove within the prosthesis for additional stability and comfort (Figure 8).

To further secure the structure and improve biocompatibility, a flowable dental composite resin (DENTEX®, Dentex Co., Ltd, China) was applied around the wire entry points and cured with ultraviolet (UV) light (Figure 9). Additional resin was used to reinforce wire stability and enhance the aesthetic appearance. The entire surgical process, from anesthetic induction to completion of prosthetic fixation, was completed within approximately 15 minutes, minimizing anesthesia duration and associated risk.

Anesthesia was reversed using 0.03 ml of Flumazenil (Flumazenil®, HIKMA FARMACÊTICA, Portugal) at a dose of 0.1 mg/kg, administered intramuscularly into the pectoral muscle. Postoperative monitoring was conducted until the bird fully regained consciousness and exhibited stable vital signs (Figure 10). In this case, a CT scan was performed after recovery for illustrative purposes to visualize the positioning of the prosthesis and surrounding craniofacial structures (Figure 11). However, this imaging step is not routinely included in the standard clinical protocol.

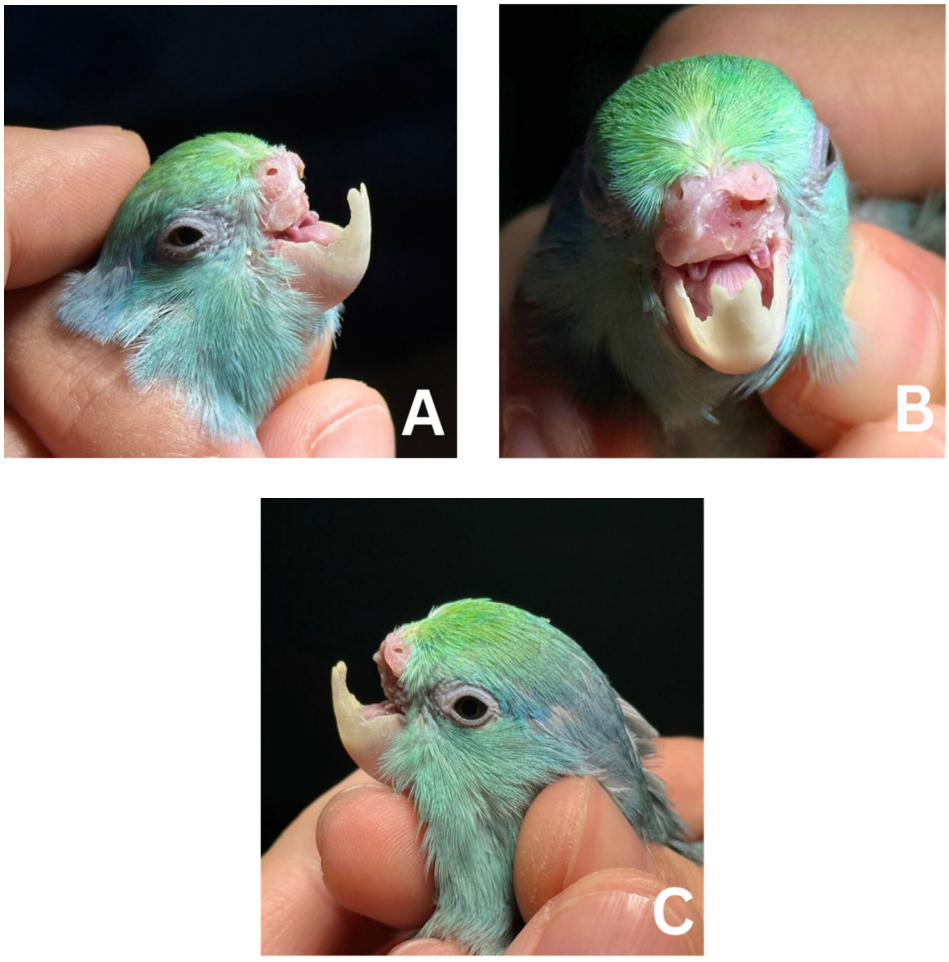


Figure 5. Preoperative views of the cleaned cere and oral cavity with healthy granulation tissue. (A) Right lateral view, (B) frontal view, and (C) left lateral view.



Figure 6. A titanium alloy orthodontic miniscrew was inserted into the midline of the remaining rhinotheca to serve as a mechanical anchor for prosthetic fixation.

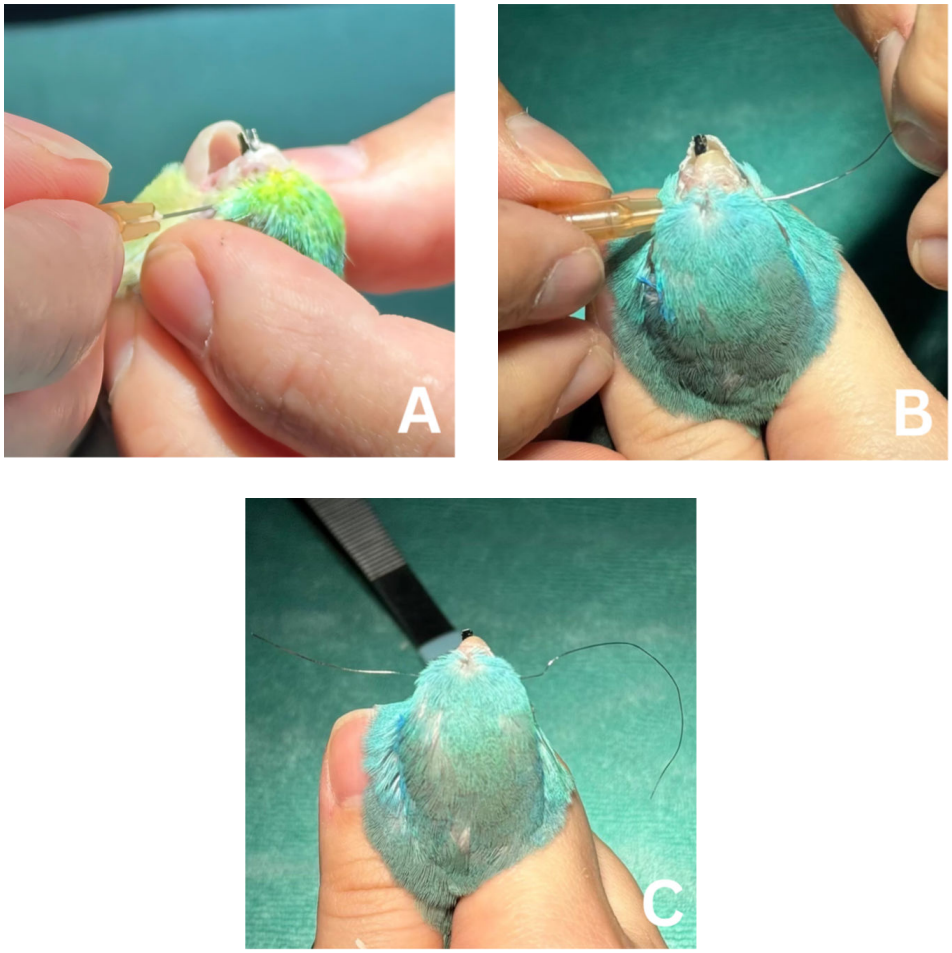


Figure 7. A 25G hypodermic needle was used as a guide (A) to pass a 0.2 mm stainless steel wire transversely through the cranial region, between the medial canthus and the base of the rhinotheca (B, C).

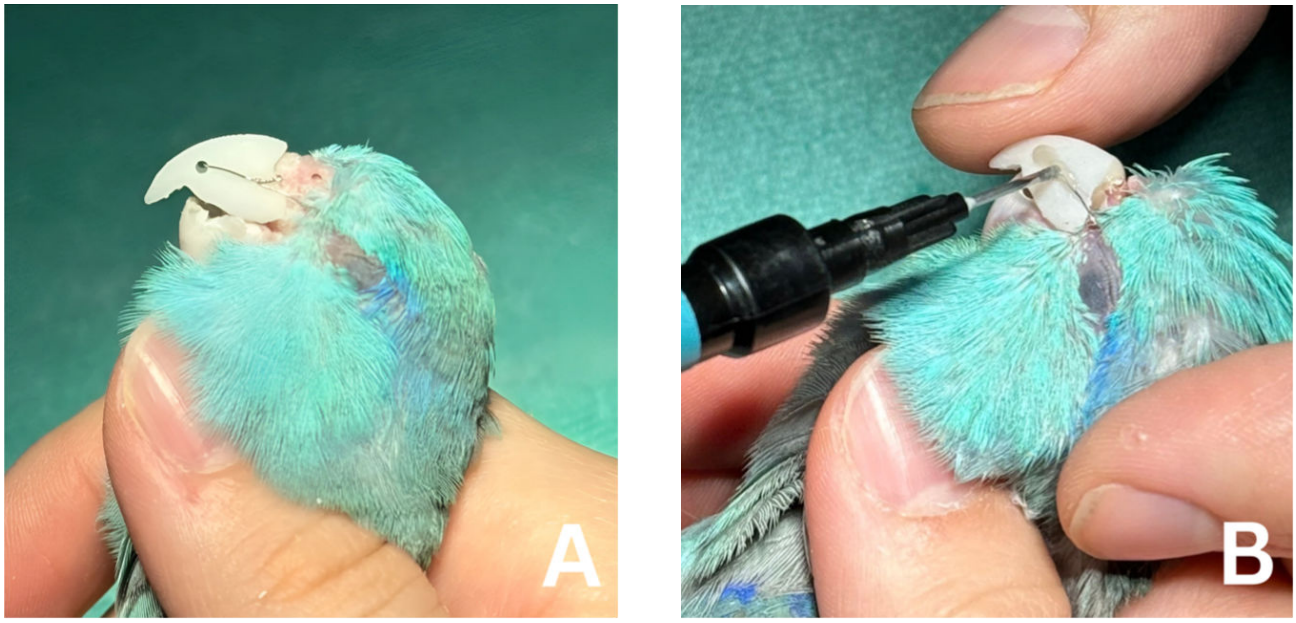


Figure 8. The stainless-steel dental wire was twisted and tucked into the prosthesis groove for stabilization (A), followed by application of flowable dental composite resin to seal the wire entry points and enhance biocompatibility (B).



Figure 9. Ultraviolet (UV) light was applied to cure the flowable dental composite resin around the wire entry points.

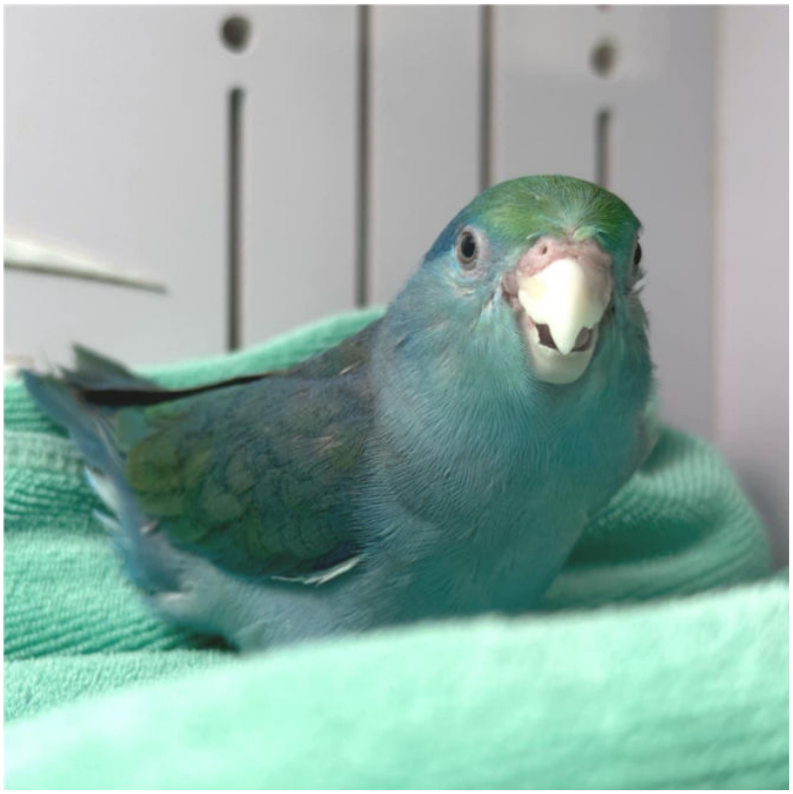


Figure 10. Completed assembly of the 3D-printed upper beak prosthesis in a Pacific parrotlet (*Forpus coelestis*) following surgical fixation.

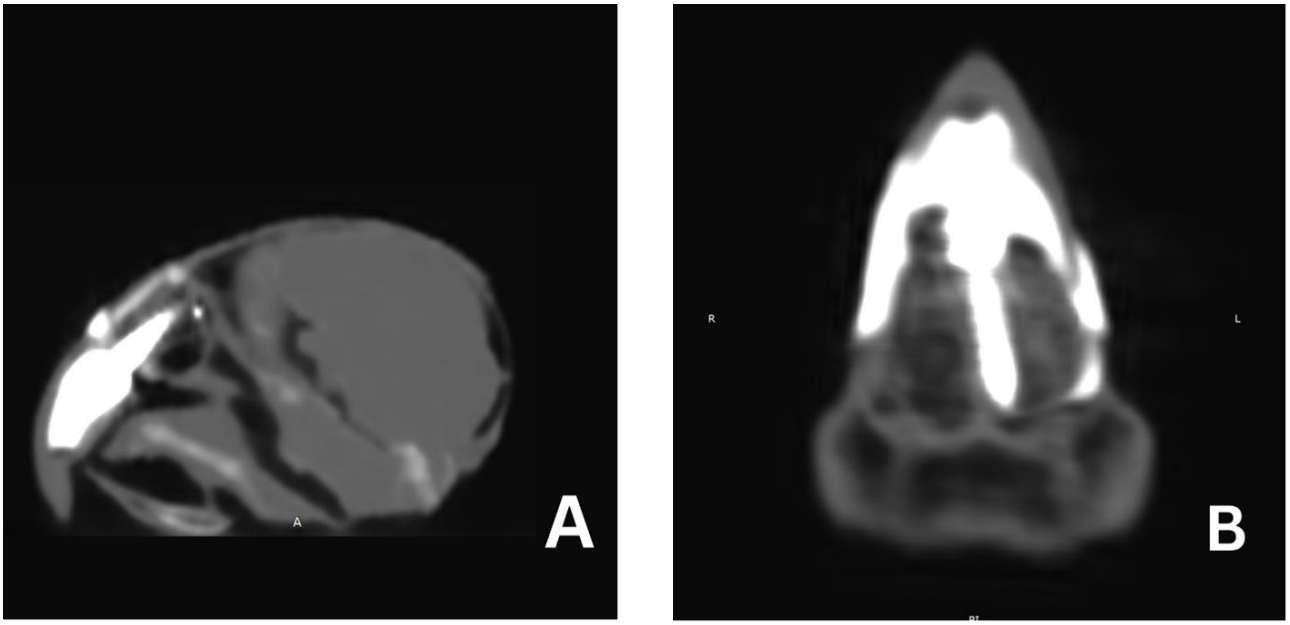


Figure 11. Postoperative CT images of the parrotlet's head after prosthesis placement. (A) Sagittal view and (B) dorsal view show the mini screw anchored solely within the remaining rhinotheca, without penetrating the supraorbital sinus.

Due to the anatomical proximity of the beak base to critical structures such as the nares and the supraorbital sinus, specific precautions were taken during surgical fixation. First, care was exercised when placing the titanium miniscrew to avoid penetrating the supraorbital sinus, which could lead to intracranial complications. Second, during the application of flowable dental composite resin, the material was precisely confined to the prosthesis interface, ensuring that it did not overflow and obstruct the nares or airway. Lastly, the surgical team closely monitored intraoperative bleeding from the wound edges to prevent blood aspiration, especially given the bird's small airway size. These measures collectively minimized surgical risk and supported a safe, complication-free procedure.

Postoperative care and outcome

Following surgical implantation of the 3D-printed upper beak prosthesis, the bird recovered uneventfully from anesthesia and showed no signs of acute discomfort or prosthesis instability. During the first postoperative week, the owner was advised to limit the parrotlet's activity by confining it to a smaller enclosure and placing food dishes at floor level to minimize climbing behavior. This environmental adjustment helped promote secure integration of the prosthesis by limiting excessive use of the beak during early healing. By postoperative day 3, the bird began self-feeding on soft food and demonstrated progressive improvement in functional use of the prosthetic beak. Throughout the first several months, the prosthesis remained stable and enabled the bird to perform essential behaviors such as grooming, perching, and interacting with its environment. Although the bird was unable to consume hard-shelled seeds, it maintained adequate nutrition on a soft food diet and crushed seeds prepared by the owner.

Due to the lack of natural beak-to-beak wear mechanisms typically provided by contact between the upper and lower beak, routine maintenance was necessary to prevent overgrowth of the lower beak. The owner was instructed to perform trimming of the lower beak every 1-2 weeks to maintain proper alignment and prevent excessive pressure or misalignment against the prosthesis, which could result in loosening or material deformation.

At approximately one year postoperatively, granulation tissue developed at the interface between the prosthesis and the cere, gradually exerting pressure that led to partial loosening of the implant (Figure 12). The prosthesis was electively removed to allow soft tissue recovery. A follow-up CT scan was performed after implant removal to evaluate the condition of the remaining rhinotheca and adjacent structures. The scan revealed insufficient rhinothecal structure to support re-implantation. The cere showed signs of hyperepithelialization at the contact area; however, the nare remained patent with no obstruction, and the bird maintained normal respiration (Figure 13). Despite the removal, the bird maintained satisfactory body condition with no signs of distress or nutritional deficiency, as the owner continued supportive feeding using a soft diet and hand-rearing formula.

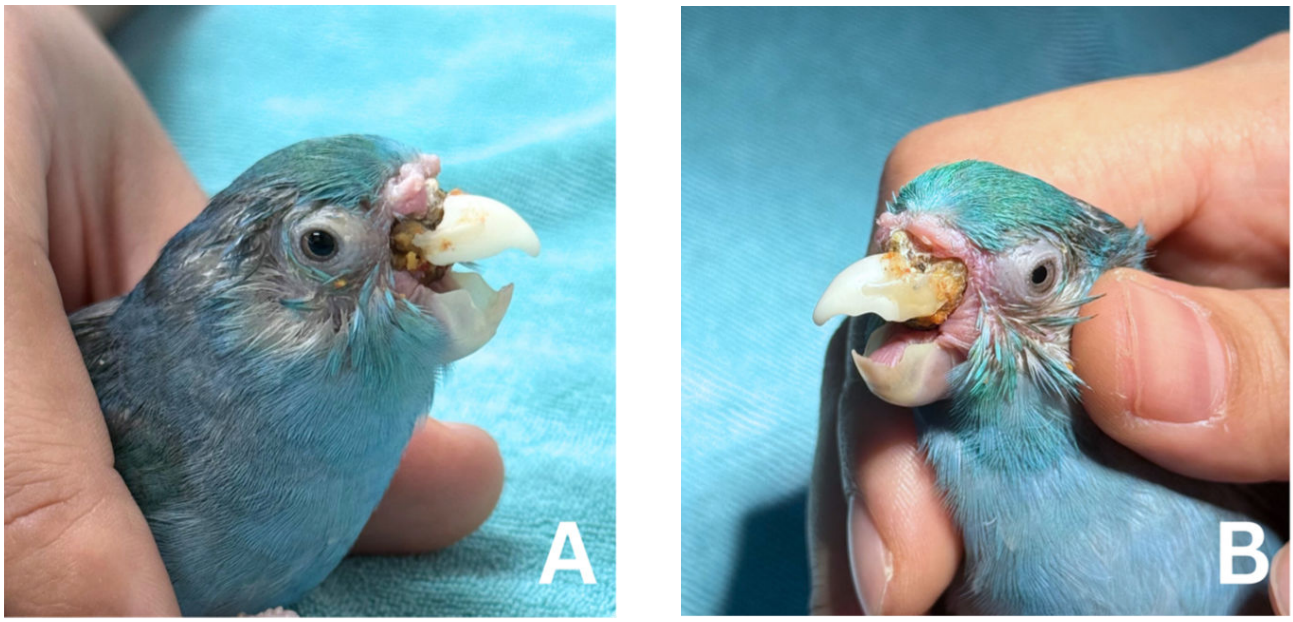


Figure 12. Right (A) and left (B) lateral views at one year postoperatively, showing granulation tissue formation at the prosthesis and cere interface, resulting in gradual displacement and partial loosening of the implant.

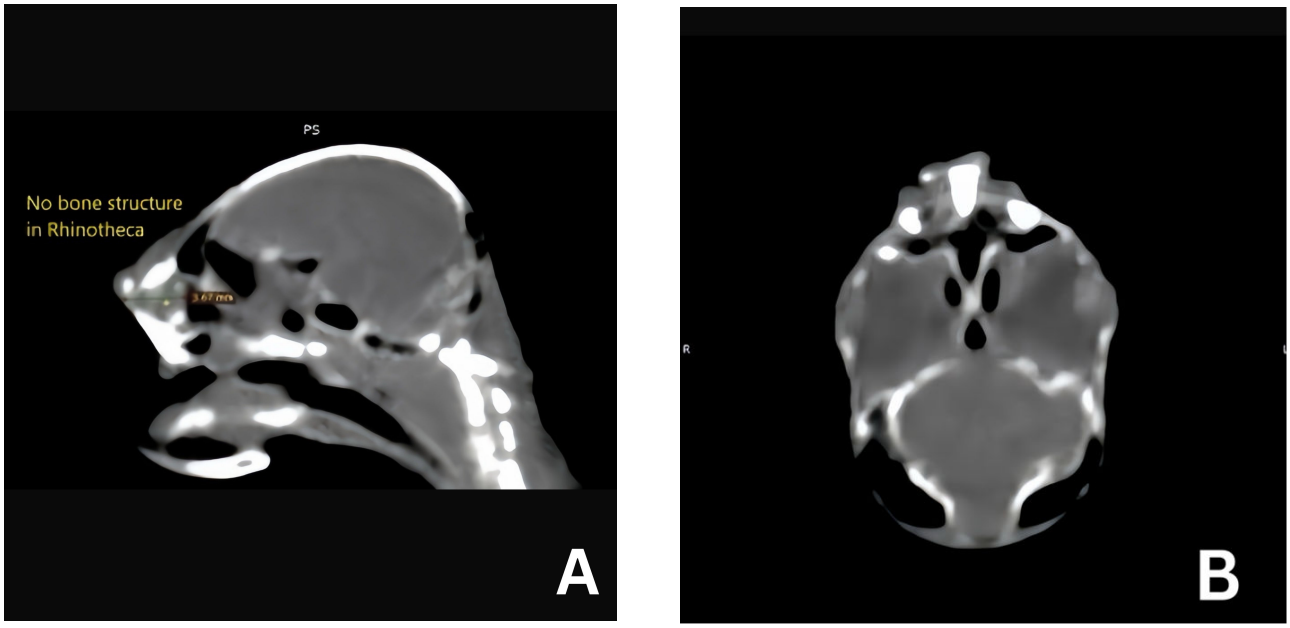


Figure 13. CT-scan images after prosthesis removal. (A) sagittal view shows insufficient rhinothecal bone for reattachment and cere hyperepithelialization. (B) Dorsal view confirms patent sinus with no obstruction.

At 8 months after implant removal, the bird was observed consuming ground pellet food independently, as shown in Figure 14, while still receiving supplemental hand-rearing formula from the owner. Although the prosthesis had been removed, its temporary placement allowed the bird to regain natural behaviors for example pecking and preening during the period it was in place. This underscores the functional significance of prosthetic intervention in restoring natural behavior and improving quality of life, even if only temporarily.

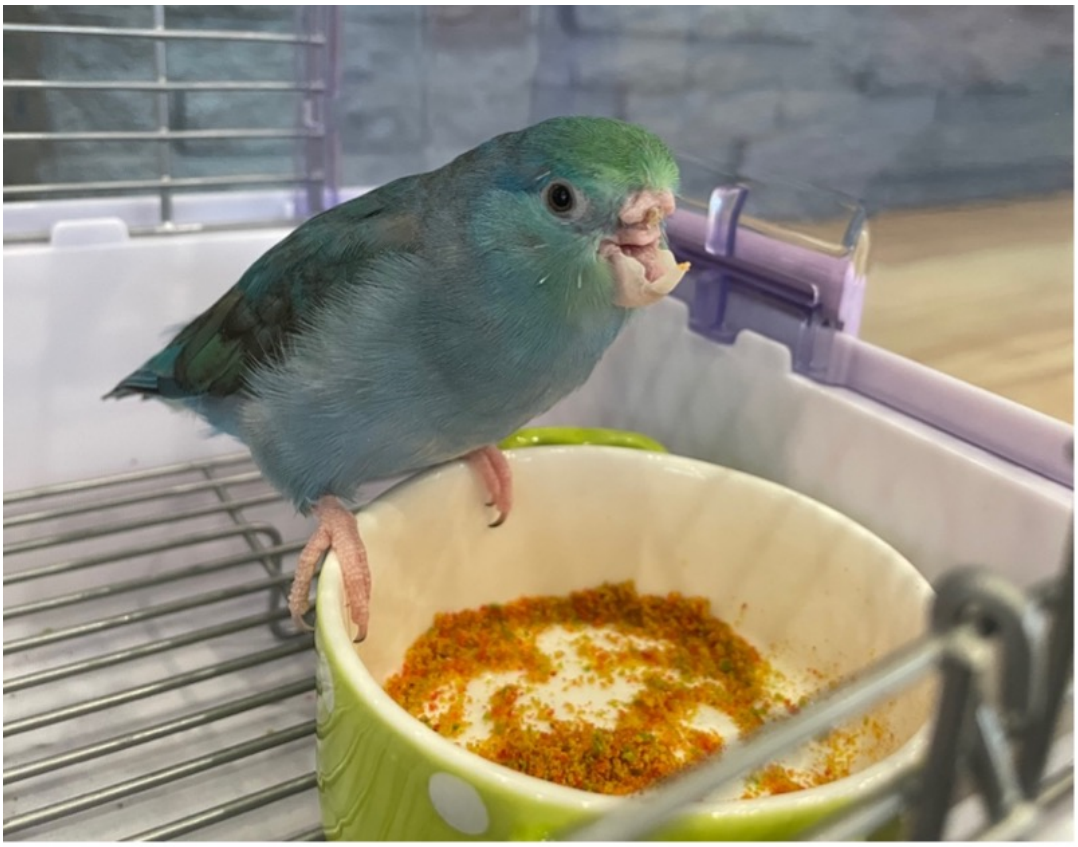


Figure 14. A Pacific parrotlet (*Forpus coelestis*) observed consuming ground pellet food independently eight months after prosthesis removal.

Discussion

This report presents the first documented clinical application of a 3D-printed upper beak prosthesis in a Pacific parrotlet, representing a promising advancement in avian reconstructive surgery. While similar interventions have been described in larger birds, including Amazon parrots (*Amazona oratrix*) (Matta et al., 2022), cockatiels (*Nymphicus hollandicus*) (Panelli Marchio et al., 2022), and green-cheeked conures (*Pyrrhura molinae*) (Patel 2021), the application in small psittacines remains rare due to anatomical and biomechanical challenges. Conventional methods such as the use of metal scaffolds, dental acrylics, or improvised materials have been associated with poor anatomical matching, instability, and limited biocompatibility, particularly in miniature species (Steenkamp 2014; Emily and Eisner 2021). Notably, in some reports, the post-operative follow-up period is limited or lacks detailed outcome assessment, with few providing clear data on prosthesis longevity. However, Panelli Marchio et al. (2022) reported prosthetic stability up to 15 months without complications, suggesting promising long-term feasibility.

In this case, the use of a stereolithographically printed prosthesis allowed for accurate anatomical restoration and resulted in a lightweight, durable, and biocompatible

design. These features are critical in smaller birds, where craniofacial load bearing must be minimized. The prosthesis was carefully designed to fit over the residual rhinotheca, preventing direct contact between uncured photopolymer resin and soft tissues. To further enhance biocompatibility, a dental composite resin barrier was applied at the interface, reducing the risk of irritation while simultaneously improving the prosthesis's mechanical integration and surface finish.

The entire implantation procedure, including prosthesis fitting, fixation with a titanium miniscrew and dental wire, and composite resin application, was completed within approximately 15 minutes. This reduced surgical and anesthetic time, which is especially important in small avian species like parrotlets that have high metabolic rates and are prone to anesthetic-related complications (Young et al., 2022). By combining customized preoperative planning with a rapid and secure fixation method, this approach offers a clinically valuable, efficient, and welfare-oriented solution. Furthermore, its adaptability may support broader applications in both small and large avian species requiring beak reconstruction.

From a biomechanical perspective, the bird's recovery reflected a rapid and successful adaptation. By the third postoperative day, the parrotlet was able to consume soft food independently and perform essential behaviors such as food manipulation and perching, suggesting strong neuromuscular adaptability and initial prosthesis integration. However, the artificial surface of the prosthetic beak lacks the friction properties of natural keratinized tissue, preventing normal wear-based regulation of the lower beak. As a result, mandibular overgrowth can occur, which may lead to mechanical stress, dorsal displacement, or loosening of the prosthesis. To mitigate these risks, routine lower beak trimming is essential (Harcourt-Brown 2023). In this case, the owner was instructed to perform trimming at home every 1-2 weeks to maintain proper occlusion and reduce mechanical loading on the prosthesis. Veterinary teams should highlight the importance of this long-term maintenance during postoperative counseling and provide guidance on monitoring growth and trimming techniques. Regular follow-up appointments may also be necessary to ensure the prosthesis remains stable and functional over time.

Approximately one year post-surgery, the prosthesis began to show signs of loosening, likely due to granulation tissue formation at the interface with surrounding soft tissue. This may have been influenced by repeated mechanical stress during feeding and grooming, which gradually displaced the prosthesis dorsally. As a result, elective removal was performed to avoid further complications. While several previous case reports have demonstrated successful application of prosthetic beaks, most have reported outcomes within short- to medium-term periods, typically spanning a few weeks to several months (Patel 2021; Matta et al., 2022; Kim et al., 2023). Longer-term retention has been mentioned in some cases. For instance, Marchio et al. (2022) reported a 15-month duration, but they often lack comprehensive documentation of tissue responses or

post-removal outcomes. In contrast, the present case provides both functional and clinical follow-up data over the course of nearly one year, offering important insight into the medium-term viability and biological interaction of a 3D-printed prosthesis in a small psittacine species. These findings highlight the potential of this technique for welfare improvement and emphasize the need for continued refinement in prosthesis design and fixation methods to achieve longer-lasting outcomes across avian species of varying sizes.

Currently, there are no standardized criteria for selecting candidates for prosthetic beak implantation. Rather than relying on strict eligibility guidelines, each case is carefully evaluated on an individual basis. Our primary consideration is the potential to improve the bird's quality of life. In situations where the natural beak is lost beyond the point of regeneration, providing a functional prosthesis, even if temporary, offers the bird a chance to regain fundamental behaviors such as feeding and object manipulation. From our perspective, choosing not to attempt reconstruction would mean the patient remains permanently without a beak, and thus without the possibility of regaining normal function. Therefore, we strive to develop tailored approaches that suit the specific anatomical and clinical conditions of each patient.

Despite this success, we must acknowledge certain limitations. As a single-case study, generalizability remains limited. The technique relies on access to advanced imaging (CT), digital modeling software, and 3D printing equipment not readily available in all veterinary facilities. Furthermore, while the materials used were well tolerated in this case, longer-term evaluations, including histological assessments, are needed to better understand prosthesis-tissue interaction and risks such as stress accumulation or micromotion at fixation sites.

We developed a set of prefabricated 3D-printed prosthetic beaks based on anatomical references to address these practical limitations and promote wider clinical applicability. These include size variations ranging from -10%, -5%, 0%, +5%, to +10% relative to the standard upper beak dimensions of the Pacific parrotlet. This library of ready-to-use prosthetic beaks enables veterinarians to select the most anatomically suitable size without requiring case-specific CT imaging or in-house 3D printing facilities. Moreover, these standardized prostheses have been made available to partner veterinary hospitals, accompanied by workshops and surgical training seminars hosted by our team. These initiatives aim to disseminate the knowledge and practical skills required for successful prosthetic beak implantation, ensuring that this innovation can be applied in real-world settings and ultimately improve the welfare of more avian patients.

Future improvements in prosthesis fixation would also benefit from closer interdisciplinary collaboration with veterinary biomedical engineers. Such cooperation could lead to more refined designs, materials, and fixation methods tailored to the anatomical and functional needs of avian patients, thereby enhancing the longevity of the prosthesis and advancing animal welfare.

Conclusion

In conclusion, this case provides compelling evidence for the viability of 3D-printed prosthetics in small avian patients and paves the way for broader clinical adoption. With appropriate refinements and increased accessibility to digital fabrication technologies, this approach could evolve into a standard of care for avian beak reconstruction. This surgery may not have been complex or dramatic, but its impact was profound. A bird that once could not eat, climb, or groom was given the chance to live normally again. The 3D-printed beak was not just a prosthetic, it was a restoration of function, freedom, and dignity. This work may not change the world. But for this one parrotlet, the world changed completely.

Acknowledgements

This project was funded by the National Research Council of Thailand (NRCT). The authors would like to express their sincere gratitude to the veterinary team for their invaluable contributions during the surgical procedure and postoperative care, as well as to the engineering team for their expertise in 3D scanning and printing, which made this work possible.

References

Dickinson E, Young MW, Granatosky MC. Beakiation: how a novel parrot gait expands the locomotor repertoire of living birds. R Soc Open Sci. 2024; 11:231397.

Fecchio RS. Avian fractured and maloccluded beaks. In: Emily PP, Eisner ER, editors. Zoo and wild animal dentistry. Hoboken (NJ): John Wiley & Sons, Inc.; 2021. p. 87-118.

Harcourt-Brown NH. Anatomy and physiology. In: Harcourt-Brown NH, Chitty J, editors. BSAVA Manual of Psittacine Birds. 2nd ed. Gloucester: British Small Animal Veterinary Association; 2023. p. 7-21.

Kim HJ, Cho C, Kim KT. Application of 3D-printed prosthetic lower beak in an Oriental stork (*Ciconia boyciana*). J Vet Med Sci. 2023;85(9):1156-60.

Lessner EJ, Echols MS, Paul-Murphy JR, Speer BL, Holliday CM. Grey parrot (*Psittacus erithacus*) beak papillae and nerves identified using novel 2-D and 3-D imaging modalities. Am J Vet Res. 2023;84(7): ajvr.23.03.0059.

Matta T, Eshar D, Nau MR. Surgical repair of a rostral maxillary beak fracture using an improvised metal implant scaffolding and dental acrylic prosthesis in a pet double yellow-headed Amazon parrot (*Amazona ochrocephala oratrix*). Isr J Vet Med. 2022;77(4): 214-8.

MyVet Imaging. MyVet CT i3D [Internet]. MyVet Imaging; [cited 2025 Aug 7]. Available from: https://www.myvetimaging.com/.

Panelli Marchio MÄ, Magalhães TV, Minto BW, Gosuen Gonçalves Dias LG. Use of acrylic resin prostheses in the treatment of rhinothecal fractures. J Zoo Wildl Med. 2022;53(2):480-4.

Patel VA, Bhadesiya CM, Gajjar PJ, Anikar MJ. Prosthetic fixation of beak in a green cheek conure (*Pyrrhura molinae*) using telemedicine. Pharma Innov J. 2021; 10(1):585-8.

Shilo D, Emodi O, Blanc O, Noy D, Rachmiel A. Printing the future-updates in 3D printing for surgical applications. Rambam Maimonides Med J. 2018; 9:e0020.

Steenkamp G. Beak repair. Proceedings of the 39th World Small Animal Veterinary Association Congress. Cape Town, South Africa: World Small Animal Veterinary Association; 2014. p. 275-6.

Tokita M. The skull development of parrots with special reference to the emergence of a morphologically unique cranio-facial hinge. Zool Sci. 2003;20(6): 749-58.

Xie S, Cai B, Rasidi E, Yen CC, Hsu CD, Chow WT, et al. The use of a 3D-printed prosthesis in a great hornbill (*Buceros bicornis*) with squamous cell carcinoma of the casque. PLoS One. 2019;14(8):e0220922.

Young MW, Dickinson E, Flaim ND, Granatosky MC. Overcoming a 'forbidden phenotype': the parrot's head supports, propels and powers tripedal locomotion. Proc Biol Sci. 2022;289:20220245.