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Minimally Invasive Maxillofacial Surgery Using Digital Work Surgery: A Case of Alveolar Ridge Reconstruction after Maxillary Cystectomy

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Abstract

Introduction: Iliac particulate cancellous bone and marrow (PCBM) is commonly used as a high-quality reconstruction material; however, PCBM cannot be extracted in sufficient amounts to meet demand. To determine the appropriate amount of iliac PCBM to be collected, we used digital technology to measure the volume required for jaw reconstruction before surgery. **Clinical Case:** The patient, a 23-year-old man, underwent surgery for a calcifying odontogenic cyst. A maxillary cyst occupied the left anterior-premolar region (tooth 21 - 25) and the deciduous canine remained; a permanent canine was included in the cyst. We planned to preserve the teeth except for the impacted canine, completely excise the maxillary cyst, and preserve the alveolar ridge morphology. Preoperative digital imaging was used to determine the amount of alveolar ridge reconstruction required and accordingly determine the amount of iliac cancellous bone to be harvested. We used a titanium mesh tray and grafts of iliac particulate cancellous bone and marrow to reconstruct the alveolar ridge. The amount of iliac cancellous bone that needed to be collected was clarified and the supply amount could be collected in just the right amount; thus, the cortical bone of the iliac inner plate could be preserved. The alveolar bone morphology was reconstructed to allow the placement of dental implants as per the preoperative digital surgery. Three years after the operation, no sign of recurrence has been observed. **Conclusion:** Minimally invasive surgery was performed by clarifying the amount of iliac cancellous bone graft that needs to be harvested, which improved the accuracy of surgery.

Keywords

Alveolar Ridge Reconstruction, Digital Work Surgery, Iliac Cancellous Bone Graft, Minimally Invasive Surgery

1. Introduction

The iliac particulate cancellous bone and marrow (PCBM) is widely used as a reconstruction material for maxillofacial bone defects. Compared with vascularized or free bone graft use, iliac PCBM use involves a simpler and less invasive procedure [1]. Furthermore, the combination of iliac PCBM and titanium mesh allows the complex morphology of the mandible and alveolar bone to be suitably shaped for implant treatment [2]. The limitations of iliac PCBM include the less quantity of iliac PCBM that can be collected [1] and the unpredictable nature of the amount that can be collected, which could lead to excess or deficiency. A transplant of cortico-cancellous autogenous iliac bone blocks or chips is performed if PCBM alone is insufficient [3]; however, because the cortical bone is an essential supporting tissue, it should be preserved if possible.

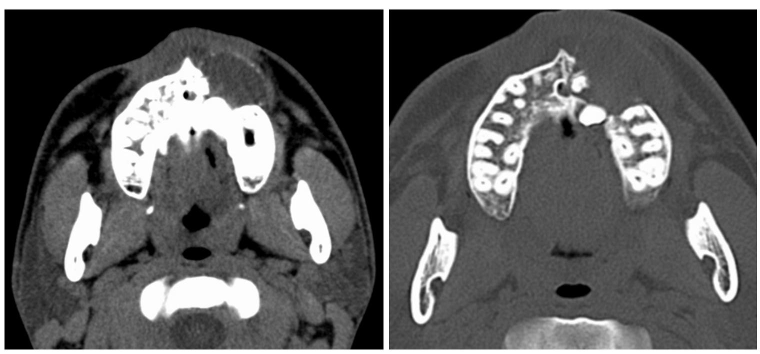
Digital technology has been used in medicine remarkably in recent years. The ability to measure tumor volume has improved [4], and reports of the use of digital technology for vascularized free bone repair of the mandible [5] and for bone augmentation prior to dental implant treatment [6] have been made. The alveolar ridge reconstruction following cystectomy was visualized and measured by the authors using preoperative digital technology. We assessed its efficacy because we were able to lessen surgical invasiveness and increase surgical precision.

2. Case Presentation

A 23-year-old man visited our department with the chief complaint of swelling of the left upper jaw. He had no medical history. He had noticed the swelling 3 months before his visit but had no pain or paralysis. Intraoral examination demonstrated swelling of the left upper anterior-premolar region without a parchment-like appearance. The left upper canine was impacted, and the upper left deciduous canine was still present. There was no tooth movement in the upper left tooth 21 - 25. The regions with swelling were covered with normal mucosa, and there was no tenderness (**Figure 1**). Orthopanorama revealed a radiolucent finding, including the impacted canine (**Figure 2**). Multidetector-row computed tomography (MDCT) revealed swelling and bone thinning in the left upper labial alveolar bone. The mass contained impacted canines and calcification (**Figure 3**). Biopsy revealed an odontogenic epithelial and ghost cell, and the pathological diagnosis of a calcifying odontogenic cyst was obtained (**Figure 4**). Surgery was planned for the total excision of the maxillary cyst, preserving tooth 21, 22, 24, and 25 and reconstruction with iliac PCBM for the bone defect. Before surgery, digital imaging was used to determine the volume needed for alveolar reconstruction. MDCT (Multislice CT Brilliance 64, PHILIPS) was used for volume measurement. Slices of the MDCT DICOM dataset were assessed in sagittal, coronal, and axial views using Osirix (the OsiriX Foundation, Geneva, Switzerland) [7]. In the cross-sectional image, the mass was manually set as the region of interest. All of the slices were digitally processed, and surface rendering was employed to construct the three-dimensional composition. The software was used to automatically determine the volume in cubic millimeters of identified maxillary cysts (**Figure 5**). We scanned alveolar bone reconstruction following excision and calculated the volume using the same technique (**Figure 6**). The volume of the maxillary cyst was approximately 11 cm^3 and that of the PCBM transplantation after cystectomy was approximately 6 cm^3.

Figure 1. Intraoral photograph at the first visit. Painless swelling of the left upper alveolar is observed. Remaining upper left deciduous canine. The upper left teeth (tooth 21, 22, 24, and 25) had no mobility.

Figure 2. Orthopanoramic X-ray at the first visit. A 3-cm circular radiograph in the left upper alveolar region containing the upper left canine. The first premolar and lateral incisor roots are spread apart, and the upper left deciduous canine is still present. In premolars, root resorption is suspected.



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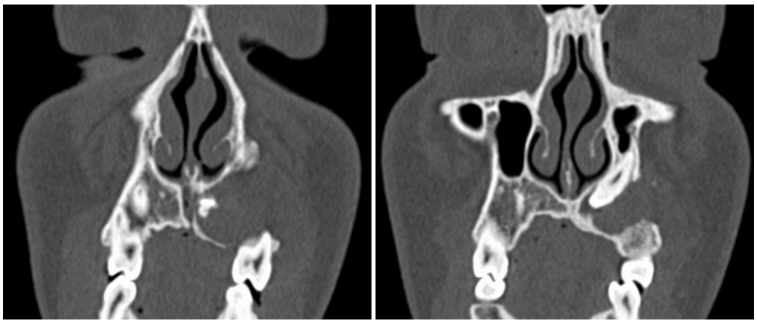

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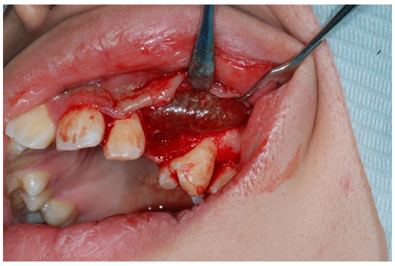
Figure 3. The maxilla from the upper left anterior tooth to the premolar is swollen. The mass contains a radiolucent lesion of calcifying and canine teeth. Canine teeth that are impacted are pushed up toward the nasal cavity.



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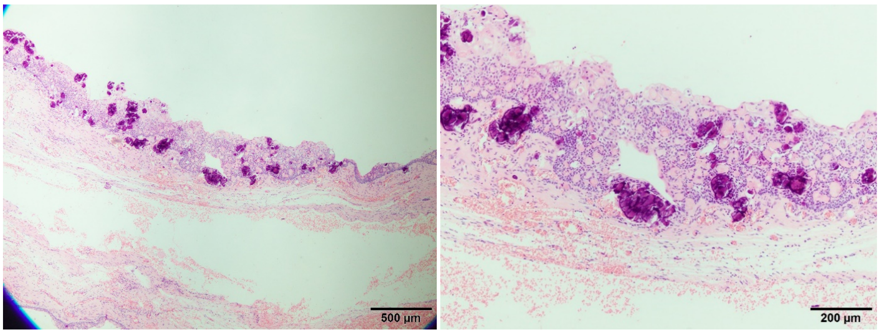
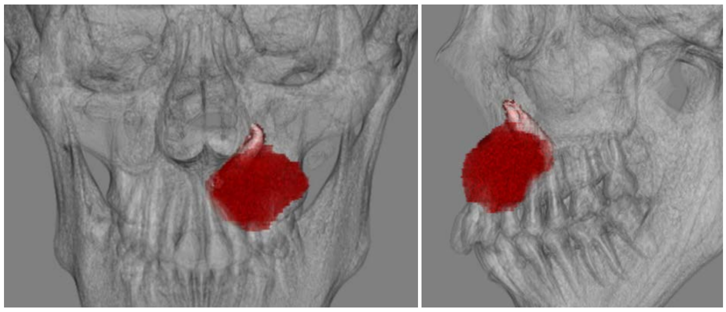


(b) (c)

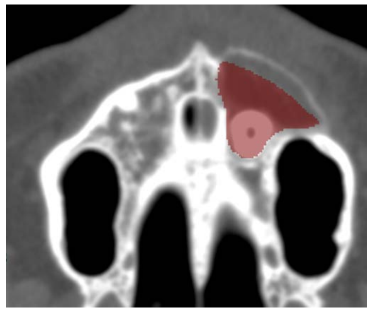
Figure 4. Biopsies were performed under local anesthesia. After extracting the upper left deciduous canine, the envelope flap was formed via a gingival sulcus incision. The tumor was a cystic lesion containing cholesterol crystals. Histopathological examination shows fibrous connective tissue forming the cyst wall. Ghost cells and hematoxylinophilic calcifications are observed in the cyst wall's inner lining.

(a)



(b) (c)

Figure 5. CT images were used to segment the maxillary cyst. The examiner manually surface-detected maxillary cysts and created its visualization 3D models of them.



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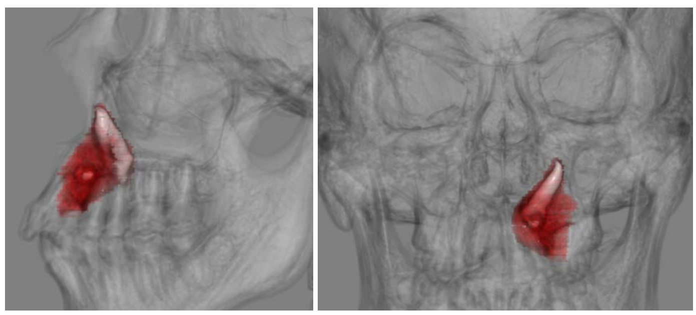
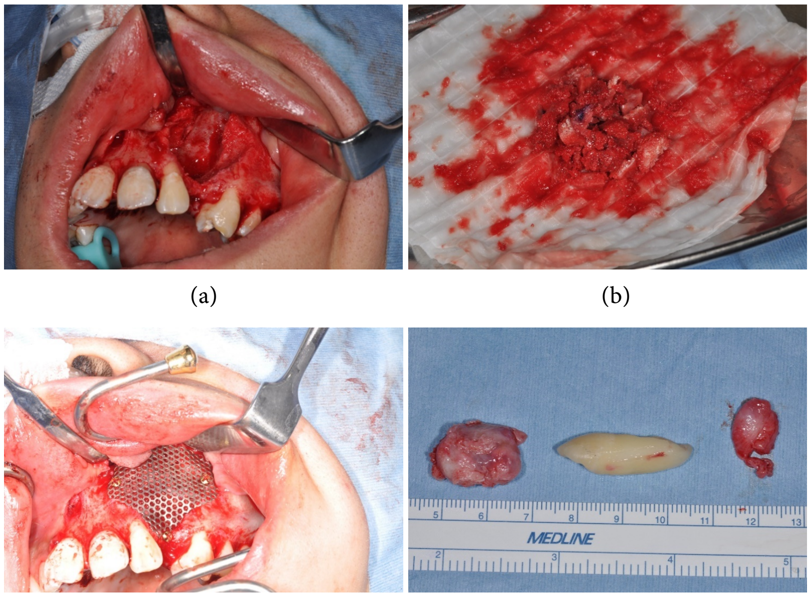


(b) (c)

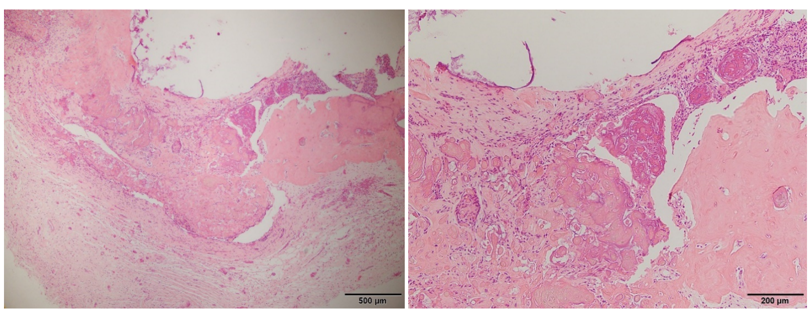
Figure 6. Preoperative digital surgical image. Digital work was done on maxillary cystectomy and alveolar bone reconstruction. The simulated alveolar bone reconstruction was shown in the healthy side symmetry. Volume rendering was performed, and the demand volume was acquired from the 3D image and measured.

The cystectomy was conducted intraorally under general anesthesia. The cyst was approached via a Neumann incision and the permanent teeth (tooth 21, 22, 24, and 25) were preserved. The cyst was completely excised, and the bone surface after excision was sufficiently scraped. The iliac PCBM was harvested using an anterior iliac crest. To harvest 12 g of complete cancellous bone and marrow, the inner plate of the iliac crest was opened with a trapdoor. After harvesting the cancellous bone and marrow, the cortical bone was then replaced. The bone defect after cystectomy was tightly filled with iliac PCBM and covered with titanium mesh (Figure 7). The results of preoperative digital surgery yielded an accurate supply volume. Considering that the outcome of the sample was determined, the surgical time was short, the patient experienced minimal postoperative pain, and was able to walk on the second postoperative day. The final pathological diagnosis was a calcifying odontogenic cyst (**Figure 8**). The cyst did not recur at the last follow-up 3 years postoperatively, and the upper left permanent tooth was in the same place and immobile. CT confirmed that sufficient alveolar reconstruction was maintained (**Figure 9**).



(a) (b) (c) (d)

Figure 7. Surgical total removal of odontogenic cyst was performed under general anesthesia. The lesion was accessed via the Neumann incision, and enucleation was performed followed by curettage. The required amount of iliac PCBM calculated by digital surgery was collected, and the inner iliac plate was repositioned. After cystectomy, the bone defect was tightly filled with iliac PCBM and covered with titanium mesh. The excised specimen had a thick, rigid cyst wall and contained an impacted permanent canine. No abnormalities are visible in the morphology and surface properties of the crown. Furthermore, a liquid component was absent in the cavity, and a calcified mass was observed.



(a) (b)

Figure 8. Palisade-shaped basal cells, which resemble ameloblastomas, make up the cyst wall's inner lining. Within the epithelial lining are variable numbers of ghost cells, which are pale eosinophilic cells with missing nuclei. There are numerous mineralizations that exhibit good hematoxylin stains.

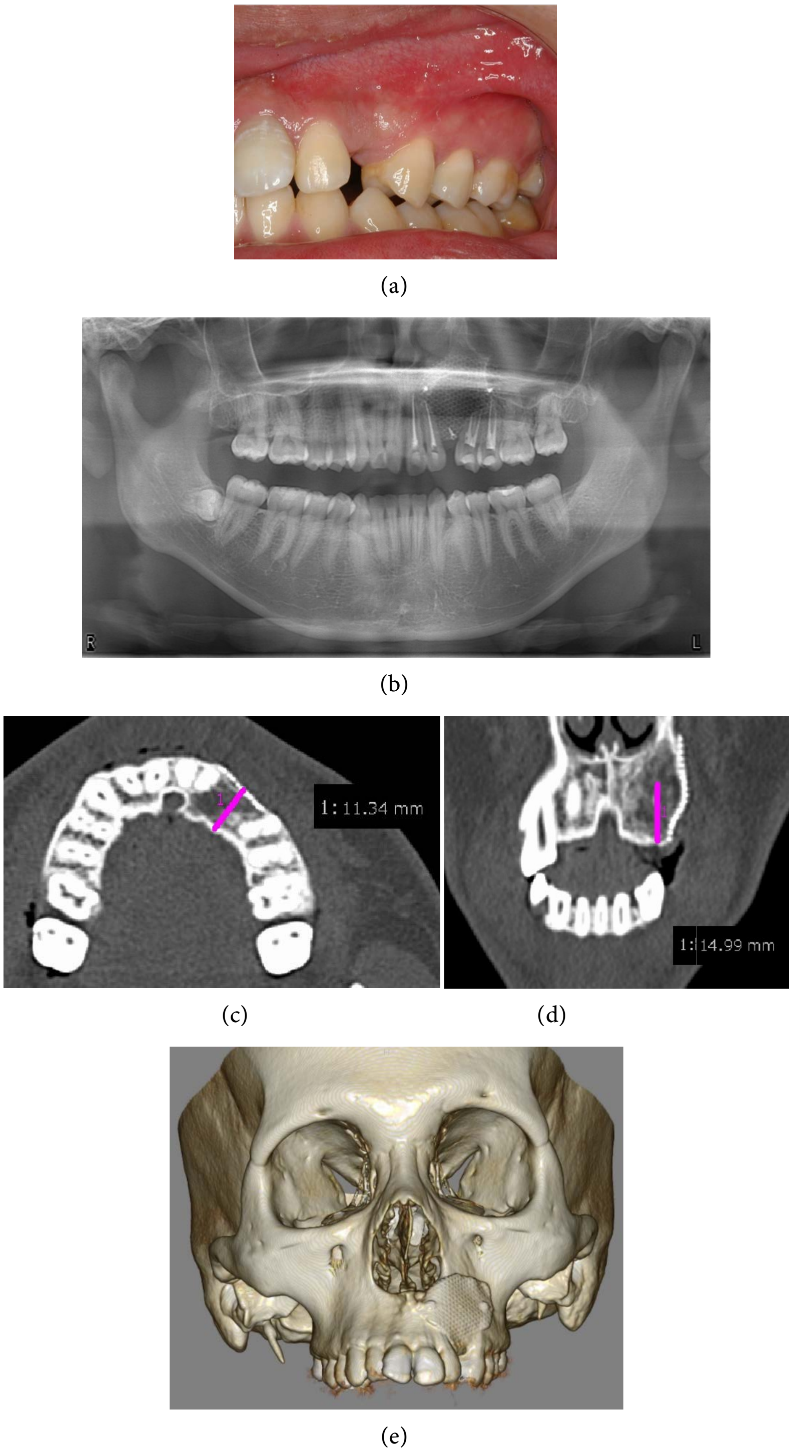


Figure 9. Three years after surgery. There are no signs of calcifying odontogenic cyst recurrence. Proper alveolar morphology is reconstituted and maintained. Sufficient bone volume and morphology has been maintained even if dental implants are required.

3. Discussion

3.1. Clinical Aspects

Digital technology is advancing medicine. Three-dimensional spatial perception elevated our diagnosis to the upper strata. Until now, surgeons have visualized three-dimensional organs using only two-dimensional CT and MRI images before surgery and have planned the surgery by themselves through trial and error. Digital imaging has made it possible to repeat and memorize surgical procedures. Surgeons can now deliver more detailed considerations. The operative field can be viewed from multiple angles, including the back side, and anatomical structure on the approach can be intentionally removed. Furthermore, visualization of results can be used to communicate surgical strategies to the surgical team. High-resolution images can be used to create 3D models that can enable practice of surgical procedures and customization of implants before surgery and be used as surgical navigation tools. The ability to consult on the cloud without being constrained by space or time is very advantageous. Digital imaging that enhances diagnosis also takes postoperative response into account. Minimally invasive surgery reduces the physical and mental burden on patients and is expected to shorten hospital stays [8] [9]. In this case, we used digital imaging of the surgical plan to reduce the invasiveness of the procedure by minimizing the surgical field. It will be feasible to perform procedures in the field of maxillofacial and oral surgery with less surgical invasiveness, in less time, and with better surgical team communication and procedure efficiency. With digital medical technology advancements, surgical precision can be anticipated to significantly increase [10].

After surgery to remove a large jaw cyst, bone defects remain, and the jawbone becomes narrow. Bone defects with three or more teeth (≥30 mm) cannot self-regenerate and must be filled with autogenous bone [11]. Particularly in young patients, a treatment plan should be made to preserve or reconstruct the alveolar ridge in good condition so that even if they lose their teeth in the future, they can receive a rigid and aesthetic occlusion reconstruction. We plan to conduct bone grafting immediately after maxillary cystectomy if the risk of recurrence is low after carefully considering the pathological diagnosis. The scarred oral mucosa and narrow oral vestibule caused by several surgeries compromise oral hygiene and are a disadvantage of dental implant treatment [12]. Unsurprisingly, immediate autologous bone grafting carries a risk of disease recurrence [13]. If the disease has a high risk of recurrence, bone grafting is scheduled 6 - 12 months after primary treatment. Whether bone grafting should be performed immediately or sometime after the resection of large odontogenic cysts or tumors remains unclear [14] [15].

3.2. Research Prospects

Improvements in digital technology, software, and apps have made it possible to measure tumor volume. In this case, the reconstructed alveolar ridge was planned on preoperative digital images to determine the amount of bone graft that would be needed. A previous study reported that the amount of iliac PCBM collected was approximately 2 g/cm^3 [16]. Typically, the required amount of PCBM cannot be obtained accurately during the surgical procedure in which the graft bed is formed and the iliac PCBM is collected at the same time. As a result, this preoperative digital imaging has reduced operating room time and increased surgical accuracy. Volume measurement, in this case, involved the examiner's subjective manual segmentation, which made it time-consuming, with poor reproducibility [17]. We can anticipate the usage of artificial intelligence to segment data automatically or semi-automatically to handle this problem. Additionally, a singular individual team completed this digital work. Only the surgical operator can predict the result of alveolar bone repair. A digital operator carefully modified the clear image of the surgical operator to produce a 3D image. The outcome was a precise demand measurement. To put it another way, bioimaging performed without surgical operator guidance might result in a guess. Intrajaw lesions can be analyzed via CT because of the high X-ray contrast of the object. Cone beam computer tomography (CBCT) is superior because of its low exposure and high spatial resolution. In contrast, CT may not be sufficient for evaluating extra jaw lesions. Soft tissue lesions and enhanced radiographic lesions may be helpful from integration with other modality imaging (MRI, scintigraphy, echo, etc.). Fusing and comparing different data, along with 3D models and artificial intelligence, might aid surgical simulation. When used for navigation, surgical techniques might be even less annoying. The use of VR and XR technology may enable repetitive surgical training. The authors believe that the fusion of surgery and digital technology will advance medical care.

4. Conclusion

Surgeons have always repeated trial and error to enhance the degree of perfection and accuracy. The consistency between conventional diagnosis and treatment planning has changed recently as a result of the addition of new technologies, such as digital technology. Digital technology improves traditional surgical protocols and will benefit many surgical disciplines, including maxillofacial surgery. We believe digital technology will be one way to conduct minimally invasive and highly accurate surgery. In this case, we used digital imaging, particularly virtual design and quantification techniques, to achieve minimally invasive surgery.

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Authors' Contributions

All authors: 1) made substantial contributions to the study concept or the data analysis or interpretation; 2) drafted the manuscript or revised it critically for important intellectual content; 3) approved the final version of the manuscript to be published; and 4) agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study complied with the Declaration of Helsinki and obtained the informed consent of the subjects.

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Consent for Publication

Images are entirely unidentifiable, and there are no details on individuals reported within the manuscript.

Availability of Data and Material

Data available on request due to privacy/ethical restrictions

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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