Two case reports stereolithographic model's role as a pre-surgical diagnostic and communication tool

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Abstract

***Objective*: This study evaluates the effectiveness of stereolithographic models in diagnosing and treating complex dental inclusions, analyzing their impact on surgical and orthodontic planning and the reduction of intra- and post-operative complications.**
***Materials and Methods*: Three-dimensional stereolithographic models were created from CBCT scans and printed in transparent resin. In the first clinical case, a 15-year-old female patient presented with complete inclusion of two horizontally impacted upper canines. The 3D model enabled precise localization of the teeth, guiding extraction through a vestibular approach and targeted osteotomy. In the second case, a 10-year-old had a malocclusion and was absent in 1.1 tooth. An OPG confirmed the presence of two supernumerary teeth: canine-like and rotated mesiodens. A 3D-printed model using a CBCT scan was created for surgical planning.**
***Results*: Stereolithographic models facilitated accurate diagnosis, detailed surgical planning, reduced operating time, and minimized risks. During procedures, they improved flap design, lesions, and identification of dental structures. Additionally, they promoted better communication with patients, reduced parental anxiety, and made outcomes more predictable. However, limitations related to cost and dependence on the surgeon's expertise were identified.**
***Conclusions*: Stereolithographic models proved to be practical tools for diagnosis and interventions, improving precision and communication. Despite technological and cost-related limitations, the evolution of 3D printing promises broader applications in the medical field.**

Keywords: stereolithographic 3D model; orthodontic planning; surgical planning; impacted canines; Mesiodens; Cone Beam Computed Tomography.

Introduction

Stereolithographic models are three-dimensional reproductions of digital data created using CAD-CAM software. In recent years, their use as aids in orthodontic diagnostics and planning oral and maxillofacial surgery has increased (1). Unlike conventional imaging diagnostic techniques, such as panoramic radiographs and Cone-Beam CT (CBCT), which provide valuable information on bone size and

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geometry, stereolithographic models accurately reproduce the three-dimensional anatomical area of interest. These models precisely guide both the diagnostic process and the surgical operation, aiming to improve preoperative form and function while minimizing surgical and postoperative morbidity (1-2). A CBCT scan is required to create these models, which are converted into a scaled stereolithographic model through 3D printing software. The model is produced using transparent resin to visualize the bone structures and internal anatomical structures involved, such as the path of the inferior alveolar nerve or, as in these clinical cases, fully impacted teeth or radicular cysts (3). These three-dimensional models have demonstrated several advantages, such as more accurate diagnostic planning, orthodontic and surgical, significant reductions in operating time, reduced wound exposure time, improved communication with colleagues and patients, and more predictable surgical outcomes. Dental inclusion is defined as the failure of a tooth to erupt, remaining embedded in the maxillary or mandibular bone after its period of physiological eruption. It can be partial or complete and is most commonly seen in third molars, followed by maxillary canines. Unlike third molars, maxillary canines are of great functional importance, playing a key role in controlling mandibular excursion movements (4-5). Yamamoto G.'s classification (6) is based on three fundamental criteria to describe the position of the impacted canine:

1. Mesio-distal position: a. The canine is positioned mesially to the first premolar.
   b. The canine is positioned betweenthe first and second premolars.
   c. The canine is positioned distally to the second premolar.
2. Bucco-palatal position: a. The canine is located palatally.
   b. The canine is centrally located relative to the alveolar bone.
   c. The canine is positioned buccally (vestibular).

Tooth orientation: a. Normal angulation: The canine maintains a relatively normal angulation concerning the long axis of the tooth despite being impacted. b. Abnormal angulation: The canine is abnormally tilted, usually with a mesial or distal inclination, making spontaneous eruption difficult.

This classification helps plan the surgical and orthodontic intervention to reposition the impacted canine. The canine's localization and angulation significantly influence the difficulty of extraction or orthodontic traction and the treatment prognosis (6-7).

During the early stages of development, the maxillary bones undergo continuous mineralization as dental structures mature (8). Teeth eventually erupt into the oral cavity through a physiological process, followed by the exfoliation of deciduous teeth and their replacement by permanent teeth (9). Several genetic or local conditions can disrupt or alter this process, resulting in abnormalities such as ectopic eruptions, transpositions, agenesis, or tooth impaction (10). In pediatric patients presenting with eruption abnormalities, radiographic examination is necessary to assess the abnormality's type, degree, and extent and establish an appropriate treatment plan. Mesiodens, a mineralized pseudodental formation, arise in the maxillary midline (11) and do not correspond to deciduous or permanent teeth. These extra teeth must be extracted to prevent impaction with erupting permanent teeth and ensure normal dental development (12).

Cases presentation

Clinical Case 1

A 15-year-old female patient presented for an orthodonticconsultation in the following representative clinical case. Upon intraoral examination (Fig. 1), the patient exhibited irregular mixed dentition with delays in the eruption of the upper deciduous canine (6.3) and upper deciduous second molar (6.5). Additionally, there was a complete absence of the upper right deciduous and permanent canines (5.3/1.3), with the closure of the space between the first premolar (1.4) and lateral incisor (1.2). The panoramic radiograph revealed both permanent canines completely impacted within the maxillary bone and a delay in the eruption of the upper left second premolar (2.5). No bone swelling was detected on digital palpation of the vestibule and palatal mucosa, suggesting that the canine inclusion was very deep. The requested CBCT examination (Fig. 2) highlighted the type IV inclusion of the two permanent upper canines, positioned almost horizontally. The crowns are located at the level of the apical third of the central incisors in a media-vestibular direction, and the roots are fully formed in a distal-palatal direction. Due to the complexity of the case, a 3D model was requested to accurately determine the final treatment plan.

Figure 1. Intraoral foto analysis (A) right lateral, (B) frontal and (C) left lateral

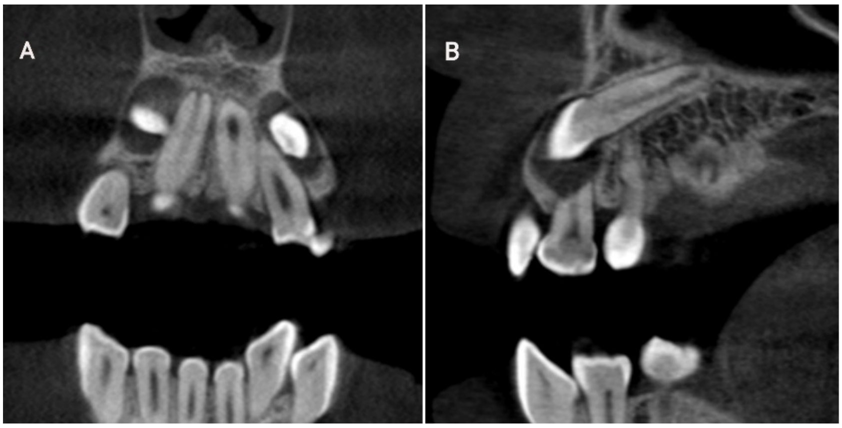

Figure 2. CBCT exam results (A) frontal and (B) lateral

Through analysis of the 3D model (Fig. 3) and a thorough study of therapeutic alternatives, it was concluded that orthodontic surgical disinclusion with anchorage of the two permanent canines was not feasible due to their position within the maxillary bone and their relationship with adjacent teeth. The presence of significant crowding with a considerable lack of space in the arch for all the dental elements and the horizontal position of the impacted teeth led to the decision to opt for the surgical extraction of both canines via a vestibular approach. The surgical procedure began with the injection of local anesthesia into the vestibule of the upper anterior sector to induce analgesia (Fig. 4 A). Two full-thickness flaps were made along the dental grooves, from the central incisor to the first premolar of both arches, with two distal relief incisions at the level of elements 1.4 and 2.4 (Fig. 4 B-C). The flaps were raised with a periosteal elevator until the vestibular wall of the maxillary bone was exposed (Fig. 5 A-B-C). Guided by the 3D model, osteotomy around the crowns of the two impacted canines was performed using a rose bur mounted on a straight handpiece (Fig. 5 D).

Figure 3. Stereolitographic 3D model (A) frontal, (B) occlusal and (C) upper side of the maxillar bone

Figure 4. (A) local anesthesia injection in the vestibular side, (B) incision and flap open on the right side (C) on the left side

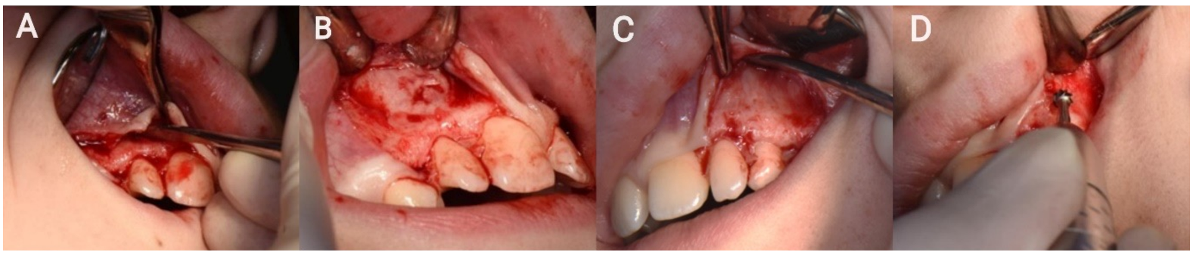

Figure 5. (A) lifting flap start with periosteum elevator (B) till uncovering vestibular wall of the maxillary bone on the right side (C) and the left side of the patient. (D) ostectomy around the canine crown

Once the two crowns were sufficiently exposed, luxation of the two teeth was carried out using a straight elevator, followed by extraction of both elements (Fig. 6). Finally, the two flaps were repositioned with sutures using interrupted stitches, and a five-day antibiotic therapy was prescribed along with pain management as needed. The sutures were removed after 15 days, and the patient was referred for a follow-up visit to plan for fixed orthodontic treatment.

Clinical Case 2

A 10-year-old pediatric patient presented to Gubbio Hospital in Italy for their first visit. During the extraoral examination, the patient's facial profile appeared asymmetrical, with an aesthetic defect caused by malocclusion in the maxillary anterior region. Intraoral examination revealed normal tooth development, with the maxillary permanent premolars fully erupted and occluded. However, tooth 1.1 (upper right central incisor) was absent in the maxillary anterior region. Palpation of the buccal and palatal bones revealed a bulge, suggesting the most likely diagnosis of tooth impaction, ruling out agenesis (Fig. 7).

Since the patient had never undergone any prior X-ray examination, an OPG image was taken to confirm the nature of the impaction and formulate a treatment plan (Fig. 8). The radiographic exam revealed that tooth 1.1 was impacted due to the presence of two supernumerary teeth. One resembled a canine, while the other resembled a rotated mesiodens, with a crown positioned near the anterior nasal spine. Due to the complexity of the case, which required careful monitoring, a CBCT scan (Fig. 9 A-B) was ordered, and the procedure was scheduled in the hospital's operating room under general and local anesthesia.

To further study the position of the supernumerary teeth and plan the surgical approach, a stereolithographic model of the patient's maxillary bone was 3D-printed. Using bicolor resin allowed clear visualization of the teeth and their roots within the maxillary bone (Fig. 9 C-D). Precise inspection of the relationship between the supernumerary teeth and adjacent teeth was critical for the success of the surgery. Additionally, given that the mesiodens were completely rotated and embedded in the anterior nasal spine, the least traumatic access route was determined by studying the 3D model. This model was also shown to the patient's parents to explain the exact location of the teeth to be extracted and the complexity of the procedure. After the parents understood the nature of the surgery, including where the incisions would be made and which teeth would be extracted, informed consent was obtained. The model was sterilized and brought into the operating room to serve as a guide during the surgical intervention.

On the day of surgery, the patient was placed under general anesthesia, and local anesthesia without vasoconstrictor was administered to numb the infraorbital nerve and anterior superior alveolar nerve. Palatal infiltration was also performed to prepare for the palatal incision and flap. The first flap was raised palatally, and a straight handpiece with a round tungsten-carbide bur was used to expose the first supernumerary tooth (Fig. 10 A). Once the tooth was freed on the palatal side, a buccal flap was raised with two releasing incisions,

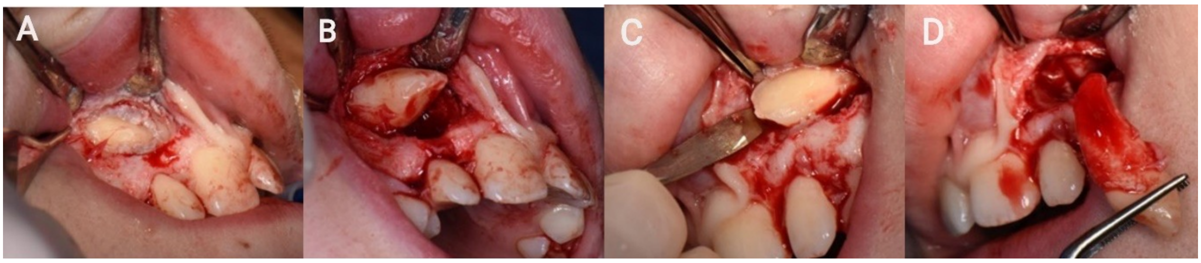

Figure 6. (A) fully exposed canine crown, (B) tooth dislocation of the right canine and (C) the left one, (D)canine extraction

Figure 7. Clinical intraoral exploration

Figure 8. Preoperatory OPG

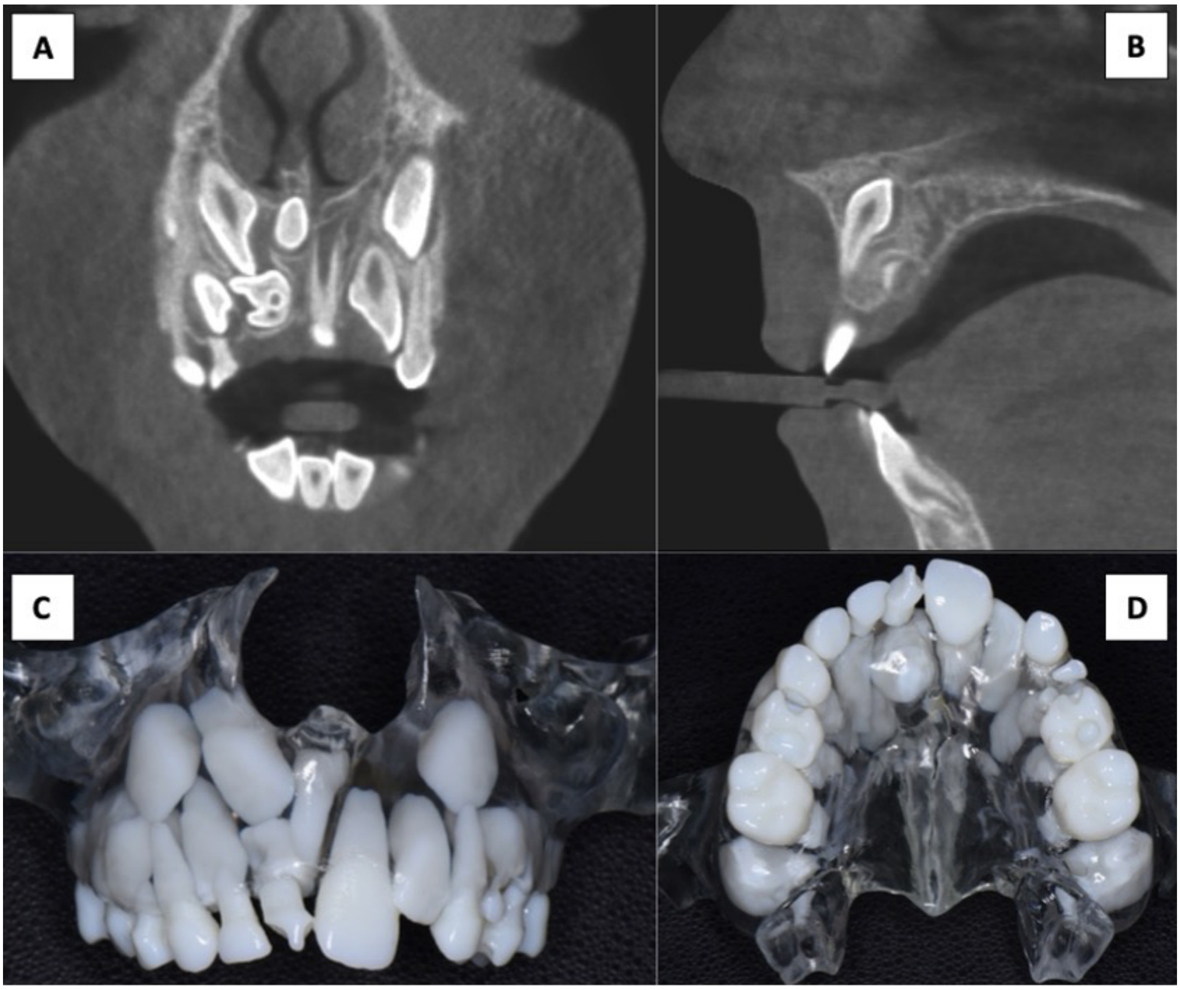

Figure 9. (A): Frontal CBCT cut showing impacted supernumerary and element 1.1; (B): CBCT sagittal cut showing mesiodens relation to ANS inside maxillary bone; (C): Stereolithographic model frontal view; (D): Stereolithographic model palatal view.

and the tooth was removed, leaving a significant bone defect (Fig. 10 B). The remains of the follicular cyst were removed, exposing the root of the mesiodens. Further bone was removed around the root, and the tooth was extracted with a rotary movement to free it from the dense, bony borders of the anterior nasal spine (Fig. 10 C). Sutures with 2/0 silk were placed to prevent flap reopening, and an antibiotic and analgesic protocol was prescribed (Fig. 10 D). The sutures were scheduled to be removed after two weeks, and the patient was monitored over the following year to determine the need for orthodontic treatment.

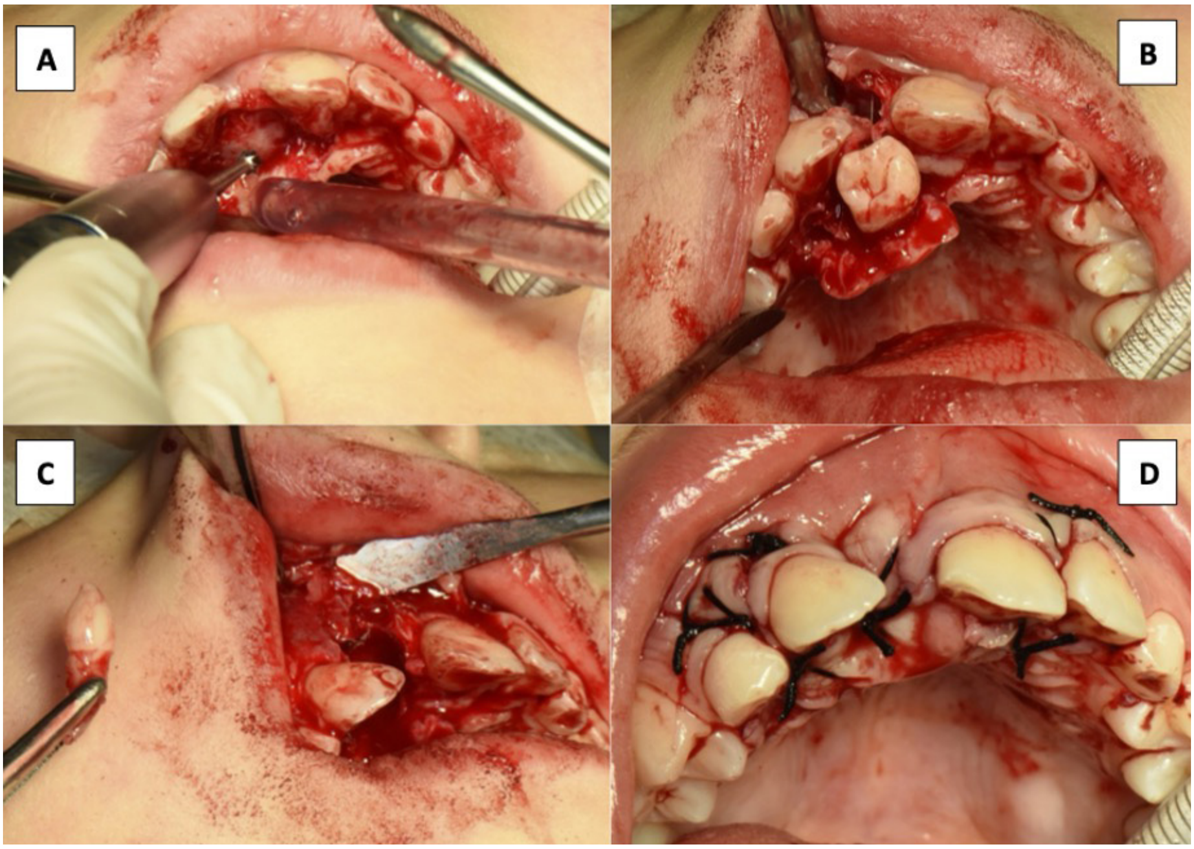

Figure 10. (A): Palatal flap and round tungsten-carbide bur used to access first supernumerary element; (B): First supernumerary extraction using buccal access flap; (C): Extraction of mesiodens from maxillary ANS position; (D): Placed sutures in 2/0 silk thread.

Discussion

As demonstrated in those clinical cases, stereolithography offers numerous advantages in oral surgery. Allowing the surgeon to plan and simulate the procedure in detail before the operation significantly reduces margins of error and enhances surgical precision, as observed in other cases of impacted canines performed without stereolithographic models.

Visualizing the patient's anatomy in detail enables the surgeon to assess the position of delicate structures in advance, such as the inferior alveolar nerve or the maxillary sinus. This reduces the risk of postoperative complications. Accurate surgical planning also shortens operating room time, as the surgeon has already rehearsed and simulated the case on a three-dimensional replica before the actual procedure, as observed in cases conducted with and without stereolithographic models.

Furthermore, communication with the patient becomes significantly easier and more direct. In cases like this one, when the patient is a minor, the presence of a tangible model helps reduce the anxiety of the parent/guardian after they can visualize and fully understand the planned procedure.

Despite its numerous advantages, stereolithography has some limitations, including cost. Stereolithography can be expensive due to the equipment required for 3D printing and the processing of three-dimensional models. However, these costs are gradually decreasing with the advancement of technology and its increasing adoption.

Another limitation is the reliance on the surgeon's expertise. Even with precise three-dimensional models, the procedure's success ultimately depends on the surgeon's ability to follow the planned approach faithfully. The accuracy of the surgical guide cannot fully compensate for potential human errors.

Finally, the quality of the initial scan plays a crucial role. The accuracy of the 3D model depends on the quality of the radiological imaging. Poor-quality radiographs can produce inaccurate models, potentially leading to errors in surgical planning.

With the ongoing evolution of 3D technology and the introduction of more advanced imaging techniques, such as integrating 3D CT scans with artificial intelligence, further precision in stereolithographic models is expected. Additionally, the development of new 3D printing materials, which are more durable and biocompatible, could further expand the applications of stereolithography, enabling the creation of surgical guides and definitive prostheses or implants (12).

Procedures such as orthognathic surgery, total joint replacement, and trauma care have been strengthened by 3D technology. With the universal adoption of 3D technology in clinical settings, surgical teams are now in a position where devices can be designed and manufactured directly at treatment sites with the necessary infrastructure. The integration of 3D technology has completely changed how doctors approach treatment planning and clinical outcomes. This article discusses key clinical applications and offers our perspective on the role of 3D technology in oral and maxillofacial surgery, as well as the potential future development with the introduction of four-dimensional (4D) printing (13).

The mesiodens' precise position and proximity to adjacent roots were studied meticulously using the 3D model, which provided invaluable assistance in surgical planning and intraoperative guidance. Using this modern technology allowed the surgeon to tangibly visualize the patient's internal anatomy in a way that was previously impossible. The main challenge when using 3D imaging diagnostic tools is the interpretation of the images. It is common for medical professionals to assume that patients can understand CBCT images, but this is often not the case. Converting CBCT scans into a 3D virtual reality model helps highlight essential landmarks, such as nerves and adjacent teeth, more comprehensibly. When the VR reconstructions are understood and accepted by the patient, the next step is physically producing these models via 3D printing. These physical models allow for a hands-on understanding of the surgical site, providing excellent communication tools for patients and colleagues. This approach also has significant educational value, helping students and less experienced surgeons visualize and understand the structures involved in surgery.

The two supernumerary teeth were successfully extracted without damage to adjacent teeth or structures. Antibiotic and analgesic therapy were prescribed for the first-week post-op, and the patient was monitored to assess the need for orthodontic treatment. Three weeks after the intervention, tooth 1.1 began erupting in the oral cavity, as the cause of its impaction had been removed. Correct alignment within the maxillary arch (14) will take time, as the patient is still in mixed dentition and undergoing ongoing dental development.

Conclusions

In conclusion, although potential postoperative sensory complications were a concern, removing the lesion was necessary to prevent the clinical condition from worsening and to restore the patient's overall and oral health.

The stereolithographic model played a key role in preoperative planning, providing the patient with a comprehensive understanding of their pathological condition while reducing the risk of intraoperative complications due to their unique anatomy.

In addition to the classic diagnostic tools, such a tool allows for overcoming the inevitable uncertainties in complex cases and is decisive in guiding final diagnostic and therapeutic decisions.

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Conflict of interest

There is no competing interest to declare.

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