


CLINICAL REPORT

Virtual planning, guided surgery, and digital prosthodontics in the treatment of extended mandible chondrosarcoma

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Abstract

Chondrosarcoma is among the most common primary bone tumors in adults. In the mandible, chondrosarcoma is a very uncommon malignant cartilage-producing tumor. This case report shows how virtual planning combined with other digital technologies may improve masticatory function rehabilitation in patients with enlarged mandibular chondrosarcoma. The present study reports a case of a 52-year-old male patient who was initially diagnosed with a mandible chondroma, which was successfully excised with no evidence of malignant transformation. Nevertheless, the patient's symptoms recurred after 10 years, and a subsequent diagnosis of mandible chondrosarcoma was established, prompting the need for subtotal mandible resection and reconstruction with a fibula-free flap. Following a healing period, the patient underwent dental implant surgery to restore the mandibular dental arch, which was performed utilizing computer-aided design and computer-aided manufacturing technology, with fully guided implant placement facilitated by virtual planning. In this case report, the implant position data merging process is described from the digital impression and control model to ensure optimal passive fit of the full-arch zirconia prosthesis and discuss the importance of occlusal adjustments to avoid technical and biological complications. Virtual planning and digital technologies are crucial for the effective management of mandibular defects, allowing for accurate treatment and complete restoration of mandibular function. Their use leads to improved patient outcomes and quality of life. As technology advances, their importance in treating complex medical conditions is only expected to grow.

KEYWORDS

chondrosarcoma, digital prosthodontics, mandible resection, virtual planning

Chondrosarcoma is one of the most prevalent primary bone malignancies in adults.¹ The mandible accounts for just 10% of these instances, predominantly the molar areas and mandibular symphysis.² It may develop at any age, although the typical start is between 50 and 60, and males are more likely to be affected than females.² Mucinous chondrosarcoma is the most common soft tissue chondrosarcoma, accounting for the remaining 10% of all cases.³

A discussion is necessary to determine the best surgical approach for the main tumor, considering its size, its involvement in anatomical structures, and patient desire.⁴ The decision of the surgeon and the patient may affect the surgical reconstruction, which should occur after an

open discussion of the advantages and disadvantages of the various alternatives and the anticipated functional results. In most cases, treatment consists of local surgery and chemotherapy/radiotherapy administered after the operation. According to the literature, in one-third of situations, either adjuvant radiation treatment or chemotherapy is performed, with no clear indication. While it has been hypothesized that chondrosarcomas are resistant to radiation treatment and chemotherapy, both are routinely employed as adjuvant therapies.⁴ Substantial resection remains the primary therapeutic option, and the survival rate at 10 years ranges from 30% to 80%.⁵ However, surgical removal of oral cavity malignancies often leads to intraoral deformities that might



FIGURE 1 Radiological images of mandible chondrosarcoma: orthopantomography.

compromise the oral functioning and quality of life of the patient.⁶

This case study highlights the significance of virtual planning and other digital solutions in masticatory function rehabilitation, presenting a unique treatment case of a patient with expanded mandible chondrosarcoma with a long-term history of the disease.

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A 52-year-old male patient presented with a history of mandibular enlargement and swelling. The swelling was immobile, hard in consistency, and only moderately tender upon palpation. The extirpation of the tumor was performed following a pathological examination, and the definitive diagnosis was reached—mandible chondroma—a locally aggressive tumor with chondral differentiation. Pathological examination revealed no indications of cancerous growth.

The symptoms returned 10.5 years later when the patient was 63 years old. The biopsy verified the mandible chondrosarcoma diagnosis (differentiation grade-G1) (Figures 1, 2). The tumor was composed of partially fibrosed cellular hyaline cartilage with minimal oval/round chondrocyte nuclei with minimal chondrocyte nuclear polymorphism and a small number of chondrocytes with double nuclei. The mucosal fragments did not show any pathological changes. Subtotal mandible resection from angle to angle and reconstruction with vascularized fibula-free flap using surgical cutting guides was planned virtually using Materialise Mimics software (Materialise HQ, Leuven, Belgium) (Figures 3, 4).

Surgical intervention

The main surgery was performed in June 2018: subtotal mandible resection using a surgical resection guide (from angle to angle), reconstruction with fibula free flap, and monitoring skin flap. For the flap harvesting, the three-dimensional (3D) printed cutting guide was used, and the osteotomies of the fibula preserving the periosteum were

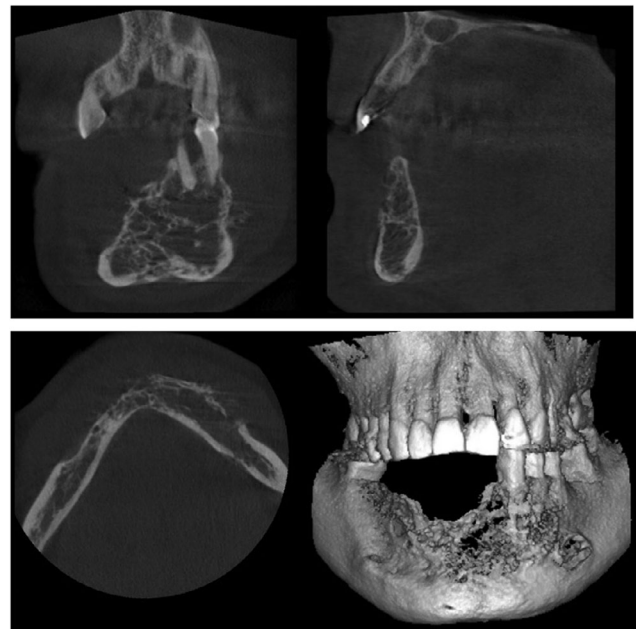


FIGURE 2 Radiological images of mandible chondrosarcoma: CBCT scans with 3D reconstruction.

performed using a Mectron Piezosurgical device (Mectron, Carasco, Italy). The bony segments of the fibula free flap were fixed to the reconstructive plate (Stryker—Leibinger, full mandibular plate, profile height 2.8 mm, SmartLock Screws 2.3 mm) using surgical guides. The reconstruction plate was prebended using 3D-printed models and guides before surgery. Although a preoperative ultrasound examination of the patient's regional lymph nodes found no obvious metastasis, bilateral neck dissection (zones I-III) was still carried out to rule out occult metastasis and take into account the patient's long-term history of the disease. The healing period was successful (Figure 5). Following the healing phase, additional soft tissue surgery under local anesthesia was performed, including vestibuloplasty and the removal of extra soft tissues (monitoring skin flap). Final pathological diagnosis—bilateral mandible chondrosarcoma pT2N0, LVI (1) (G2), radical chondrosarcoma resection.

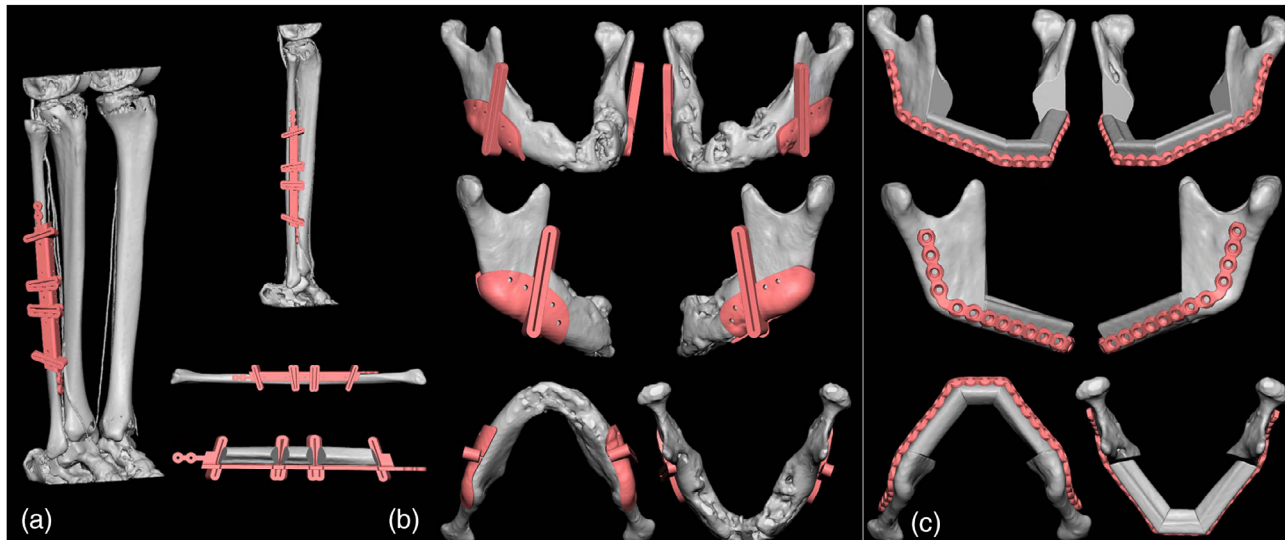


FIGURE 3 Cutting guides of (a) fibula and (b) mandibula using computer-aided design; (c) the planning of a pre-bent reconstruction plate.

Prosthetic rehabilitation

During the healing phase, the temporary removable prosthesis was made to evaluate the functional and esthetic parameters of the mandibular dental arch (Figure 6). After healing, the removable prosthesis was relined with UfiGel SC (VOCO, Cuxhaven, Germany) to ensure a good fit, and six reference marks (Fuji Plus, GC, Tokyo, Japan) were made on the removable prosthesis and a double scan procedure with cone-beam computed tomography (CBCT) machine (OP 3D, KaVo, Germany) was performed. Based on CBCT images, the virtual planning of fully guided implant placement and dental restorations was done using Implant Studio and Dental System (3Shape, Copenhagen, Denmark) software. Virtual full-arch wax-up was completed, and 6 Conelog Screw-Line (Camlog, Basel, Switzerland) implants were planned to avoid interferences with a reconstruction plate and osteosynthesis screws. Implant depth and rotational positions were selected based on the available multi-unit abutment geometries to allow a favorable insertion path of the prosthesis and locations of screw-access holes.

Fully guided placement of 6 Conelog SL implants was done using a 3D-printed guide and single-use guide drills with internal irrigation. Primary stability in the 50–70 N/cm range was achieved for all implants. Preoperatively selected multi-unit abutments were attached to the implants, and scan bodies were secured to the abutments. Intraoral scanner Trios 4 (3Shape, Copenhagen, Denmark) was used to capture the positions of the scan bodies and to register the bite for the production of the full-arch screw-retained PMMA bridge (Figure 7). Occlusal adjustments were made at the delivery of the PMMA bridge and after 2 weeks for evaluation of static and dynamic occlusion.

Scientific evidence for full-arch digital impressions for definitive implant-supported restorations still needs to be

provided.⁷ Furthermore, due to the lack of implant mobility, it is widely accepted that the passive fit of full-arch zirconia prosthesis is critical to avoid technical and biological complications.⁸ To ensure the best passive fit, a novel Total Fit Workflow (TFW) protocol (Figure 8) for merging implant position data from the digital impression and the control model was applied. Using this protocol, the passive fit is additionally evaluated with the TFW device measuring the screw-rotation angle.

The Trios 4 (3Shape, Copenhagen, Denmark) intraoral scanner (IOS) was used to scan the upper and lower arch and to register the bite with the PMMA bridge. Then, the PMMA bridge was cut into three pieces, and one of them was left in the mouth to serve as the reference (Figure 9). Four scan bodies were connected using 15 Ncm torque. The removed part of the temporary prosthesis was deleted from the scanned image, and the positions of four scan bodies were registered. Then, the remaining part of the PMMA bridge was removed and the rest of the two scan bodies were attached. Again, the removed part of the PMMA bridge was deleted from the scanned image, and the positions of the remaining two scan bodies were registered. Thus, the mandibular full-arch scan was completed.

Next, the scan bodies were disconnected, and impression copings were attached. They were splinted with a light curing material (IndividuoLux, VOCO) intraorally⁹ and the passive fit of the splint was evaluated.¹⁰ The analogues were attached to the splinted impression copings, and the control model was fabricated. The scan bodies were attached to the control model, and their positions were captured using a laboratory scanner E4 (3Shape Copenhagen, Denmark). The scan body positions from the control model were imported into the CAD software. Therefore, the final implant positions were recorded not by the intraoral scanner but by the intraorally fabricated splint and consequently produced a control

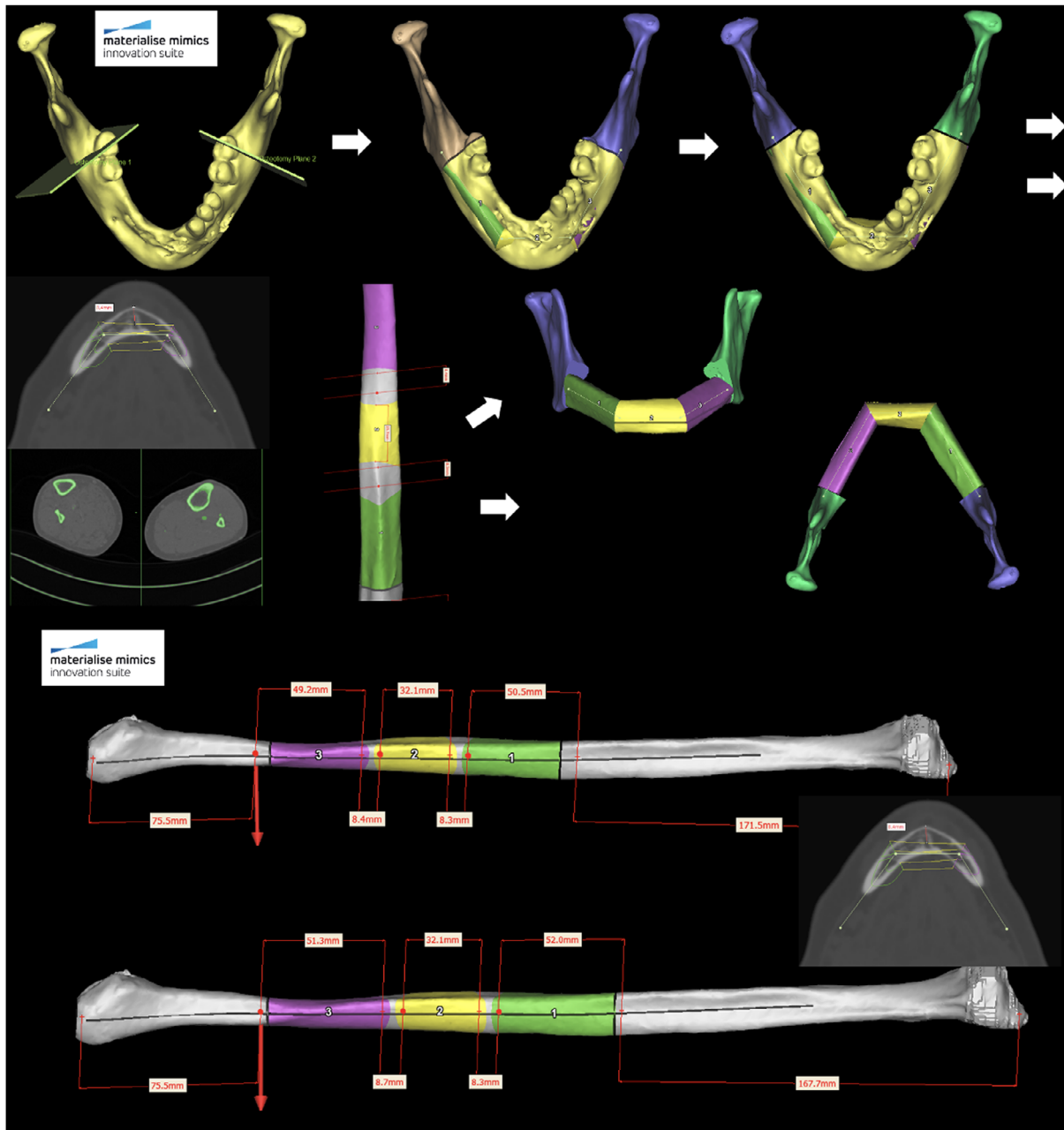


FIGURE 4 Virtual planning of subtotal mandible resection, reconstruction with vascularized fibula free flap using surgical cutting guides.

model. Full-contour full-arch prosthesis was milled from the Katana HTML (Kuraray Noritake, Tokyo, Japan) zirconia and stained (Figure 10).

The intaglio surface was left without glazing material and was highly polished. Paths for super floss passage were created to facilitate hygiene. The fit of the prosthesis was evaluated on the control model and intraorally using the Sheffield and screw resistance tests using a TFW device measuring the screw-rotation angle indicating the passive fit.¹¹ Slight occlusal surface modifications were done, and the prosthesis was delivered (Figure 11).

Three-year follow-up revealed sufficient personal hygiene, stable marginal bone (Figure 12), healthy soft tissues,

very good patient satisfaction, and absence of the disease recurrence.

DISCUSSION

According to the World Health Organization, chondrosarcoma is a malignant tumor with pure hyaline cartilage differentiation.¹² The hallmark of it is the creation of hyaline cartilage by tumor cells. This tumor is less aggressive and grows more slowly but is more likely to return without therapy.¹³ The development of this disease is gradual and takes from 0.5 to 12 months. Patients typically



FIGURE 5 Clinical image showing postsurgical status.



FIGURE 6 Temporary removable prosthesis used to evaluate the functional and esthetic parameters of the mandibular dental arch.



FIGURE 7 Full-arch screw-retained PMMA bridge.

complain about vague pain and swelling symptoms that have been present for an extended period.¹² The illness tends to reoccur locally but may metastasize in rare instances. However, chondrosarcomas' clinical history, histogenesis, cytogenetics, and prognosis still need to be clarified.¹⁴

It is worth noting that in this clinical case report, the patient was first diagnosed with chondroma, a mesenchymal-derived benign tumor. Yet, distinguishing between chondroma and low-grade chondrosarcoma can be challenging. Because of their similar radiological and clinical results, the difference between the two becomes even more unclear.¹⁵ Hence, in these situations, a thorough histological investigation is necessary to look for any signs of dysplasia, such as cellular atypia, a shift in the nuclear-cytoplasm ratio, increased cellu-

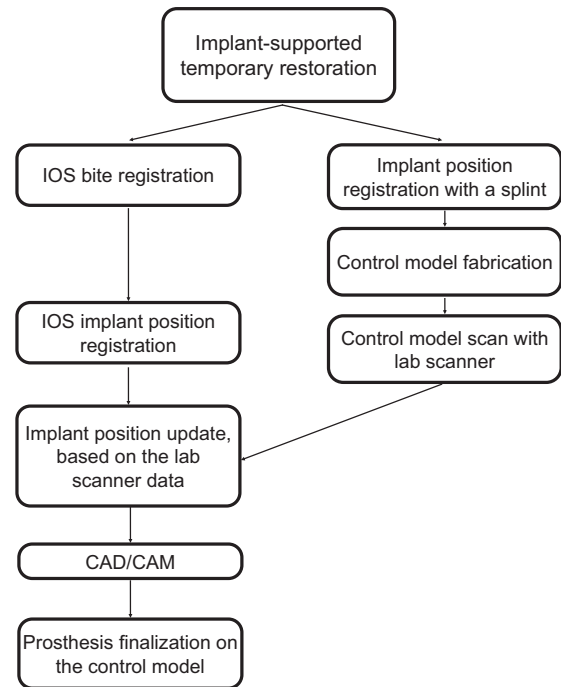


FIGURE 8 Total Fit Workflow scheme applied in the treatment.



FIGURE 9 Total Fit Workflow protocol allowed for merging implant position data from intraoral scanner and control cast to improve the workflow accuracy and to improve the passive fit. One-third of the temporary bridge was left as the reference during the intraoral scanning procedure.

larity, or other abnormalities. The literature indicates multiple chondromas have a malignant transformation rate ranging from 20% to 33%.¹⁶ The nature and type of the lesion can be determined by using conventional radiographs, computed tomography scans, and magnetic resonance imaging. Still, a histological diagnosis is required, which makes it clear that chondrosarcomas are exclusively made of hyaline cartilage and meet the criteria for cytologic malignancy.¹⁷

In this clinical case report, virtual planning (VP) technology was used to view the defect, execute mandibular resection, fibula osteotomy, and free flap inset before surgery, and provide exact cutting templates and surgical guidance. Vascularized osteocutaneous grafts have been the primary way of reconstructing big mandibular defects, but current breakthroughs in VP have enabled surgeons to try more



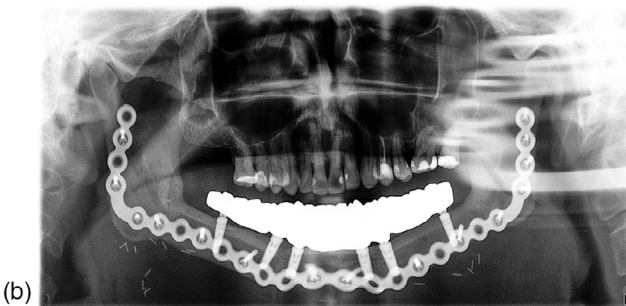
FIGURE 10 Final full-contour full-arch prosthesis.



FIGURE 11 Final prosthesis fixed in the mouth.



(a)



(b)

FIGURE 12 Follow-up after 3 years: (a) postoperative profile; (b) orthopantomography.

precise reconstructions with greater intraoperative efficiency. The fibular osteotomy, which takes an average of 1 h to perform, is believed to be the stage that presents the most difficulty and demands the most time.¹⁸ Because of the accuracy, ease, and projected patient results, computer-based surgical reconstruction planning has become more popular globally. VP technology is not novel, but recent developments in resolution, image quality, and slice thickness from CBCT scans enable more accurate 3D modeling and sophisticated surgical simulation tools. VP for head and neck reconstructive surgery is a recent use of the technology, but it is gaining popularity owing to its anticipated advantages of better precision, convenience, and results.^{18,19,20} One of the major advantages of VP seems to be increased surgical performance since it is widely recognized that lowering surgical time favors patients.²¹ Moreover, minimizing ischemia durations as low as achievable improves free flap survival rates since this is one of the leading reasons for transplant failure.²²

Oral rehabilitation and jaw reconstruction with prostheses may be difficult and are often performed in stages. Speech, swallowing, and mastication benefit greatly from implant-supported prostheses, and their incorporation into the conventional rehabilitation approach is on the rise.^{23,24} One of the treatment options is primary implant placement. This treatment minimizes total reconstruction time by lowering the number of surgeries, which enhances functional results. However, implant misplacement, radiation treatment interference, and local anatomical changes are the disadvantages of primary implant placement. It is important to consider that if the flap develops complications or does not integrate properly, both the flap and the implants are removed.²⁵ On the other hand, the secondary implantation is a two-stage process chosen for this case report. In this case, implants were inserted after the healing of the fibula flap was confirmed. Secondary implant placement has several advantages, including identifying patients who are motivated to undergo additional prosthetic rehabilitation, shortening the initial surgical procedure, confirming the viability of free fibula flap, creating an ideal implant placement guide and prosthodontic plan based on exact centric relation position, and allowing time to rule out local tumor recurrence.^{25,26} In addition, the National Health Insurance Fund under the Lithuanian Ministry of Health does not reimburse VP, implantation, or any patient-specific plates that could be used for the reconstruction of the mandible; therefore, the patient must cover all surgical and prosthetic expenses, and in the event of failure, patient funds would also be lost.

A dental workflow should be included in the surgical planning process if functionality and dental rehabilitation are the ultimate goals of reconstructive surgery.²⁷ As a result, reconstruction must prioritize implant insertion and design bone location appropriately. This method varies from the previous paradigm in that the location of the fibula does not alter the former contour of the resected bone but must provide enough bone tissue to the anticipated position of the implants. Incorporating the dental workflow into the planning is

critical to ensuring the suitability of the dental implants for a fixed prosthesis.^{27,28} In this case, it is essential to take note of the fact that the position of the digital implant was planned and adapted to the defect in such a way that none of the osteosynthesis screws needed to be removed. Furthermore, the implants were anchored into the bone, and virtual planning enabled the estimation of bone quantity and quality, allowing the primary stability of the implants to be controlled. As the fibula is composed mainly of Type 1 and Type 2 bone, the modified surgical protocol should be used to avoid excessive insertion torque and intraoperative implant complications.²⁹

Titanium bars are typically used to construct full-arch implant-supported zirconia prostheses to reduce the likelihood of technical issues and the severity of the resulting misfit.³⁰ However, in this case, an innovative technique of creating digital impressions and bite registrations was employed, utilizing additional reference objects to improve the accuracy of image suturing. Additionally, the accuracy of the bite registration was enhanced by the presence of the scan bodies. In addition, the increased passive fit was achieved using the implant positions represented by the control model, which was scanned using a laboratory scanner. Lastly, the passive fit was determined more objectively by measuring the rotation angles of the screws. This avoided the use of the complex laboratory technique of fabricating titanium bars with a one-piece zirconia overlay. A recently introduced titanium base solved the problem of an unfavorable ratio between the height of the titanium base and the crown. This base has a cementation part that is approximately 9 mm in height. Finally, the prosthesis was designed to be easily cleaned. Overall, using innovative techniques and materials, such as digital impressions and the new titanium base, resulted in a well-fitted and easily maintained full-arch implant-supported zirconia prosthesis.

CONCLUSIONS

Mandibular chondrosarcoma is a rare but serious condition that requires careful planning and execution of treatment. In severe clinical cases, virtual planning and modern digital technologies enable and facilitate the complete restoration of the mandible and masticatory function. These technologies enable more precise and accurate treatment, improving patient outcomes and a better quality of life. As technology continues to evolve, it is expected that virtual planning and digital technologies will play an increasingly important role in the management of mandibular chondrosarcoma and other complex medical conditions.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

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