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JOIS

CASE REPORT

Virtual surgical planning and 3d simulation with augmented reality in mandibular monostotic fibrous dysplasia: a case report

RELATO DE CASO

Planejamento cirúrgico virtual e simulação 3D com realidade aumentada na displasia fibrosa monostótica da mandíbula: relato de caso

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Keywords: Fibrous dysplasia; Monostotic; Augmented reality; Pathology; Oral; Case report.

Abstract

Monostotic fibrous dysplasia (MFD) is a benign, non-hereditary skeletal disorder characterized by the replacement of normal bone with fibrous tissue and immature woven bone. Although the craniofacial region is frequently affected, mandibular involvement is less common and may pose significant clinical and surgical challenges, particularly in recurrent or symptomatic cases. This case report describes a patient with mandibular MFD presenting lesion progression and persistent neuropathic pain following initial surgery. A second surgical intervention was subsequently performed using advanced digital technologies, including virtual surgical planning, 3D modeling and printing, intraoperative simulation guided by augmented reality, and customized cutting guides. Postoperative computed tomography confirmed high fidelity to the surgical plan and improvement in facial symmetry. This case highlights important advances in the application of digital technologies in oral and maxillofacial surgery, demonstrating increased precision, improved aesthetic outcomes, and enhanced anatomical preservation. To our knowledge, this is one of the few documented cases of recurrent mandibular fibrous dysplasia treated using digital surgical simulation and multiplanar cutting guides. These findings suggest that virtual planning and augmented reality may become valuable tools in the management of complex craniofacial bone lesions, increasing predictability and patient satisfaction while minimizing risks in revision surgeries.

Palavras-chave: Displasia fibrosa monostótica; Realidade aumentada; Patologia oral; Relato do caso.

Resumo

A displasia fibrosa monostótica (DFM) é uma desordem esquelética benigna, não hereditária, caracterizada pela substituição do osso normal por tecido fibroso e ósseo imaturo. Embora a região craniofacial seja um local frequentemente acometido, os casos mandibulares são menos comuns e podem representar desafios clínicos e cirúrgicos significativos, especialmente quando recorrentes ou sintomáticos. Este relato de caso descreve um paciente com DFM da mandíbula, com progressão da lesão e dor neuropática persistente após cirurgia inicial. Em um segundo momento cirúrgico, foi realizado novo procedimento, com uso de ferramentas digitais avançadas, incluindo planejamento cirúrgico virtual, modelagem e impressão 3D, simulação transoperatória guiada por realidade aumentada e uso de guias de corte personalizadas. A tomografia pós-operatória confirmou alta fidelidade ao planejamento cirúrgico e melhora da simetria facial. Este caso evidencia avanços importantes na aplicação de tecnologias digitais na cirurgia bucomaxilofacial, demonstrando maior precisão, melhores resultados estéticos e preservação anatômica. É um dos poucos casos documentados de displasia fibrosa mandibular recorrente tratado com simulação cirúrgica digital e guias de corte multiplanares. Os achados sugerem que o planejamento virtual e a realidade aumentada podem se tornar ferramentas valiosas no tratamento de lesões ósseas craniofaciais complexas, aumentando a previsibilidade e a satisfação do paciente, minimizando riscos em cirurgias revisionais.

Introducion

Fibrous dysplasia (FD) is a non-hereditary genetic disorder characterized by the replacement of normal bone with immature osseous and fibrous tissue arranged in a disorganized pattern[1]. Clinically, it may be classified as monostotic FD (MFD) (affecting a single bone) or polyostotic FD (affecting multiple bones), with the monostotic form being the most common, accounting for approximately 70% of cases[2]. The femur, ribs, and craniofacial skeleton are the most frequently affected sites[1-3]. In the monostotic form, 27% of cases involve the skull bones, and among these, only 25% affect the mandible[4].

The diagnosis of MFD should be based on a combination of clinical findings, medical history, physical examination, radiographic features, and histopathological analysis[5]. When located in the craniofacial region, the condition is referred to as craniofacial fibrous dysplasia (CFD) and typically demonstrates slow growth, frequently being incidentally detected on routine imaging examinations, particularly in monostotic cases[3]. Non-contrast computed tomography (CT) is the imaging modality of choice to assess the characteristic radiographic features and extent of the lesion[5]. Imaging commonly reveals the classic “ground-glass” trabecular appearance, often associated with loss of the lamina dura[6].

CFD may result in significant aesthetic deformities, facial asymmetry, and, in some cases, functional impairment[3,7,8]. Treatment should be individualized and is generally indicated in cases with aesthetic or functional impact[5]. Conservative surgical management allows contouring of the dysplastic bone to restore facial symmetry and relieve symptoms without complete lesion resection[9]. Most studies recommend postponing surgical intervention until skeletal maturity is reached and the lesion has entered a quiescent phase[1,5,8].

In recent years, digital technologies such as virtual surgical planning, 3D printing, and augmented reality have emerged as promising tools to enhance surgical predictability, precision, and safety[10]. The aim of this report is to present a clinical case of monostotic fibrous dysplasia of the mandible treated with virtual surgical planning and augmented reality–guided simulation, and to discuss the benefits of this approach in the context of Oral and Maxillofacial Surgery. This case report has been reported in line with the SCARE 2025 guideline[11].

Ethical aspects

This case was approved by the Research Ethics Committee of the Hospital de Clinicals de Porto Alegre (CAAE: 95129226.7.0000.5327). The patient was informed about the risks and benefits of the procedure and of participation in the study. After reading the informed documents and having his questions clarified, the patient signed the Informed Consent Form and the Authorization for Use of Images.

Case Report

A 17-year-old male patient presented to the Oral and Maxillofacial Surgery outpatient clinic at Hospital de Clínicas de Porto Alegre reporting pain and progressive swelling on the left side of the mandible. The patient reported no previous surgical intervention, no medication use, and no allergies. Following the request for additional imaging, the patient underwent bone scintigraphy and facial computed tomography (CT), which demonstrated abnormalities; however, no involvement of other bones was identified, thus excluding polyostotic dysplasia. The patient had already passed puberty and presented with significant swelling and associated pain, with surgical intervention being indicated. Bone scintigraphy revealed increased radiotracer uptake in the mandible, indicating intense metabolic activity, without evidence of other similar areas, supporting the monostotic nature of the lesion. In addition, the absence of increased bone metabolism beyond the mandible, together with the clinical findings, suggested marked deceleration of bone growth. CT imaging showed bone thickening with areas of cortical resorption suggestive of fibrous dysplasia (FD), without involvement of dental or neural structures.

An incisional biopsy confirmed the histopathological diagnosis of fibrous dysplasia. The patient subsequently underwent corrective mandibular osteotomy through an intraoral approach, aiming at functional and aesthetic improvement, Histopathological analysis confirmed the initial diagnosis of fibrous dysplasia. Despite satisfactory immediate postoperative recovery, recurrence of pain and facial asymmetry was observed within the first postoperative year.

Multidisciplinary evaluation, in collaboration with the pain management and psychiatry teams, revealed progressive lesion growth and persistent pain with neuropathic and myofascial characteristics. The patient reported allodynia, severe daily pain with functional limitation, and significant impact on daily activities, work, sleep, and quality of life. Pharmacological treatment with amitriptyline and simple analgesics was initiated, however, adherence to the prescribed regimen was incomplete because the patient reported excessive sedation and drowsiness, leading to treatment discontinuation.

The patient remained under follow-up, and a second surgical intervention was planned after stabilization of skeletal growth and partial symptom control. At 22 years of age, following completion of the growth period and stabilization of lesion size on clinical examination, the patient continued to report significant aesthetic concerns and persistent pain, reinforcing the indication for surgery. The new procedure aimed to correct facial asymmetry with the support of virtual surgical planning (VSP).

The objectives of VSP were to enhance procedural predictability, preserve critical anatomical structures, and optimize facial symmetry. Four surgical cutting guides were designed based on preoperative CT imaging.

The digital workflow for virtual planning, visualization in virtual reality (VR), augmented reality (AR), and mixed reality (MR), as well as computer-aided design and 3D printing of surgical guides and biomodels, followed these steps:

1) The patient underwent cone-beam computed tomography (GE Medical Systems, Revolution EVO; facial bone protocol with 0.625-mm slice thickness) for anatomical assessment.

2) Images were exported in DICOM format to the P3Dental virtual surgical planning software (P3Dmed, Porto Alegre, RS, Brazil).

3) After 3D reconstruction, planning was performed collaboratively with the surgical team.

4) The finalized plan was exported to the M3DMIX application (P3Dmed) for VR, AR, and MR visualization.

5) STL (STereoLithography) files were exported for computer-aided design of surgical guides and biomodels using CAD software (Rhinoceros 3D).

6) Files were processed in slicing software (Ultimaker Cura v5.6) and fabricated using fused deposition modeling (FDM) with polylactic acid (PLA) on a 3D printer (Ultimaker).

On the initial CT scan, areas of exostosis to be removed were delineated. The first surgical guide was designed for axial osteotomies, followed by a second guide for sagittal cuts. Postoperative CT with 3D reconstruction was superimposed onto the virtual plan, demonstrating high fidelity between the planned and achieved surgical outcomes (Figure 1).

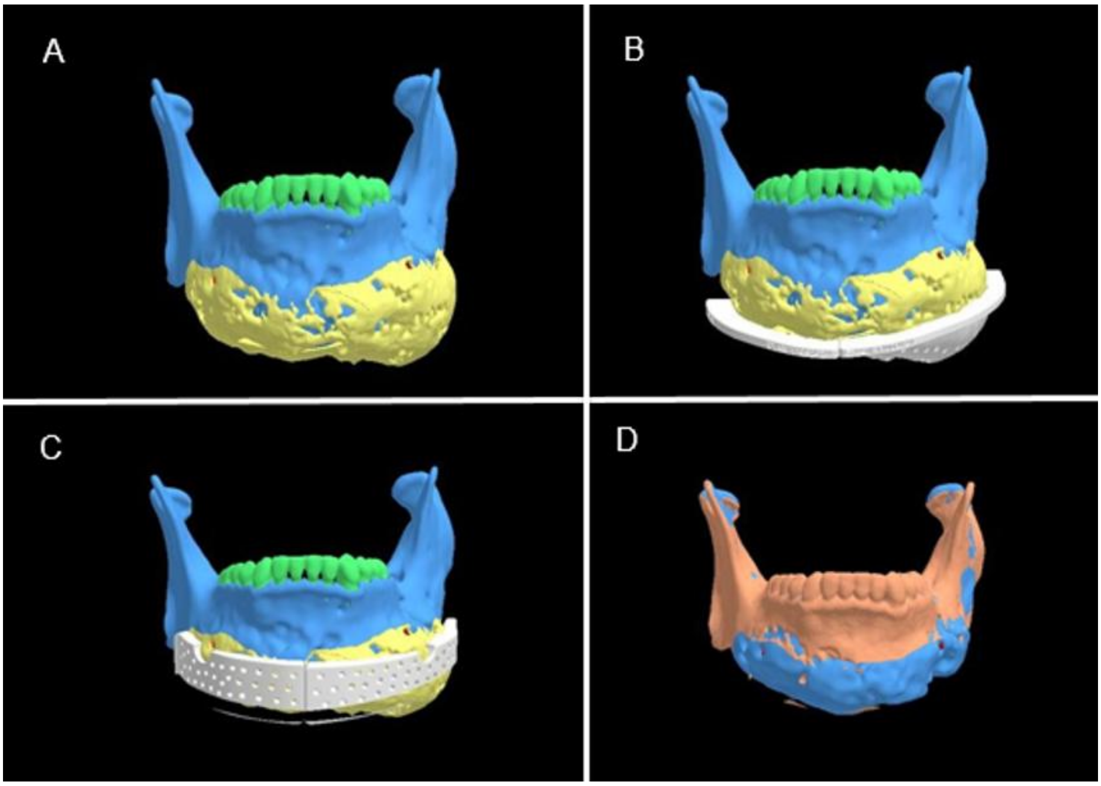

Figure 1: A) 3D reconstruction of the preoperative computed tomography scan. B) Surgical guide for axial osteotomies. C) Surgical guide for sagittal osteotomies. D) 3D reconstruction of the postoperative computed tomography scan superimposed on the virtual surgical plan.

In addition to the use of biomodels and conventional surgical guides, a surgical guide integrated with virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies was employed (Figure 2).

The QR code on the surgical guide was scanned using the M3DMIX application (Figure 3), developed by the same company responsible for the case planning (P3Dmed), enabling intraoperative visualization of the virtual surgical plan (Figure 4).

Figure 2: Biomodels and surgical guides. Surgical guide integrated with a QR code.

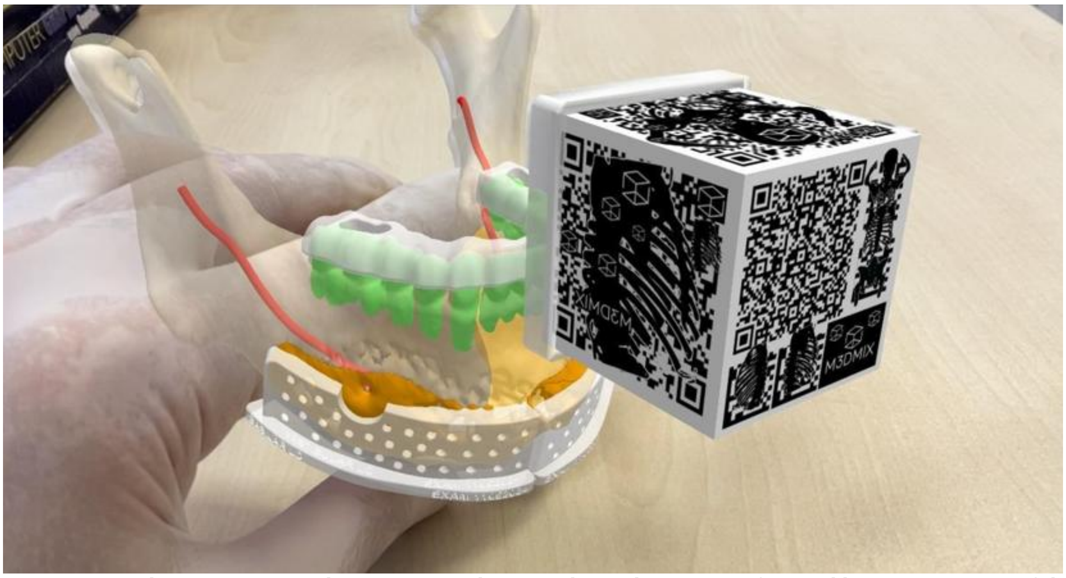

Figure 3: QR code scanning using the M3DMIX application. The application interface enables reconstruction of the mandible and surgical planning, allowing manipulation of the model, visualization of anatomical structures, and simulation of the osteotomies planned with the surgical guides.


Figure 4: QR code scanning during the surgical procedure. The application screen image allows visualization and manipulation of the surgical planning directly within the operative field.

VR, AR, and MR technologies were applied through a QR code attached to the surgical guide. When scanned using a dedicated application, this code generated a reconstruction of the structure of interest overlaid onto the surgical field. In this case, the mandible with the lesion was reconstructed, and the application allowed the surgical team to manipulate the model, simulate cuts using the planned guides, and highlight anatomical structures. This enabled the surgeon to visualize, in real time and in three dimensions, both the surgical specimen and the preoperative surgical plan.

This approach allowed the integration of the three types of reality (VR, AR, and MR). Virtual reality creates fully digital, immersive 3D environments, enabling preoperative surgical training and precise surgical planning within these simulated settings. Augmented reality brings this virtual three-dimensional environment into clinical practice by overlaying digital information, such as imaging data, onto the surgical field. Finally, mixed reality proposes the integration of the digital and real worlds, allowing not only visualization but also manipulation and interaction with virtual objects, with direct clinical impact. In the present case, all three modalities were employed. VR enabled preoperative surgical planning. AR allowed scanning of the QR code and visualization of imaging data directly on the patient's face. MR enabled manipulation of both the imaging data and the preoperative plan during the surgical procedure, including simulation of osteotomies, rotations, and highlighting of relevant anatomical structures.

Virtual surgical planning enabled a safe and effective approach, providing improved control of bony margins and superior aesthetic outcomes. Preoperative and postoperative CT images demonstrated the accuracy and effectiveness of the bone contouring performed. The histopathological result was consistent with the previous findings, confirming the diagnosis of monostotic fibrous dysplasia.

At the 30-day postoperative follow-up, the patient exhibited good recovery, satisfactory healing, and reported satisfaction with facial appearance, noting improved symmetry (Figure 5) and absence of pain.

Figure 5: A: Immediate preoperative photograph. B: 30-day postoperative photograph.

At the 20-month postoperative follow-up, the patient maintained good surgical recovery, with no clinical signs of lesion growth. The patient remained satisfied with facial appearance and denied any functional impairment. No paresthesia was reported, and occasional pain in the region was noted, which was controlled with simple analgesics. This case highlights the clinical course, multidisciplinary management, and the importance of incorporating digital technologies in the surgical treatment of recurrent craniofacial fibrous dysplasia.

Discussion

Monostotic fibrous dysplasia of the mandible, although less common than in other craniofacial skeletal sites, represents a significant clinical challenge, particularly when symptomatic and recurrent. The present case highlights several features that make it relevant and, to some extent, original in the literature.

According to the literature, the monostotic form accounts for approximately 70% of FD cases and typically demonstrates slow growth with a tendency toward stabilization after puberty[9]. However, in the present case, significant lesion progression was observed even after the initial surgical intervention and completion of skeletal development, diverging from the typical clinical course described in previous studies, which report a more predictable and quiescent behavior after the growth peak[1,12].

Another noteworthy aspect was the persistent and refractory pain. Although pain is not a common finding in monostotic FD, especially in the absence of nerve compression or malignant transformation, the patient developed chronic neuropathic and myofascial pain, allodynia, and substantial functional and psychological impairment. This presentation highlights the importance and challenges of a multidisciplinary approach, including the surgical team, chronic pain specialists, and mental health professionals, for managing complex pain associated with dysplastic bone disorders.

Regarding treatment, the originality of this case lies in the surgical approach supported by advanced digital technologies, including virtual surgical planning, customized cutting guides, and superimposition of pre- and postoperative 3D models, which has rarely been described in recurrent mandibular FD. Recent studies suggest that such technologies may reduce operative time, improve aesthetic outcomes, and potentially decrease recurrence risk, findings that were supported in this case[12-16].

The main clinical and scientific contributions of this report include the longitudinal documentation of a mandibular FD case with atypical progression, postoperative recurrence, and significant chronic pain, as well as the demonstration of the effectiveness of virtual surgical planning in the reintervention of a previously operated lesion. The use of multiple CT-based cutting guides (axial and sagittal), along with postoperative 3D image superimposition confirming surgical accuracy, further emphasizes the value of digital workflows in enhancing aesthetic and functional outcomes and patient satisfaction.

Limitations of this report include the patient's poor adherence to pharmacological pain management, which limited objective assessment of therapeutic response. Furthermore, as these are emerging technologies, the associated costs and limited access to specialized programs and software may hinder their widespread adoption. In addition, more robust studies involving these technologies are required to allow more reliable conclusions.

In summary, this report contributes to the literature by presenting an innovative and multidisciplinary approach to an uncommon clinical manifestation of monostotic fibrous dysplasia. Virtual surgical planning and customized cutting guides proved fundamental in managing a recurrent case and may serve as a reference for similar situations in oral and maxillofacial surgery practice.

Conclusion

This case report highlights the importance of an individualized and multidisciplinary approach in the management of monostotic fibrous dysplasia of the mandible, particularly in cases presenting with atypical behavior, postoperative recurrence, and persistent pain. The use of digital technologies, such as virtual surgical planning and customized cutting guides, may potentially improve procedural predictability, surgical safety, and aesthetic and functional outcomes.

This case underscores the potential of these innovations within the field of oral and maxillofacial surgery, especially in the treatment of complex and recurrent bone lesions. Nevertheless, long-term clinical follow-up and patient adherence to multidisciplinary care remain essential for adequate pain control and prevention of further lesion progression.

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