The Role of 3D Printing Technology as an Additional Tool in Unilateral Condylar Hyperplasia Surgical Planning

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Abstract: The purpose of this study is to evaluate whether additive manufactory technology through the use of 3D mandible and skull cast models can provide additional support to the virtual surgical planning for patients affected by unilateral condylar hyperplasia (UCH). This study describes 2 patients affected by active UCH. Cone beam computed tomography (CBCT) scans were converted in STL files and then sent to a 3D printer that provided 3D cast models of patient's mandible and skull. Surgical planning was conducted performing linear measurement both on 3D virtual images and on 3D cast models. Proportional condylectomy was then simulated with the virtual software and on the 3D cast models as well. After 18 months, new CBCT scans of the patients were acquired and new 3D cast models were printed. Measurements performed on the 3D cast models were close and reliable if compared to measurements obtained on 3D virtual images. None of the patients underwent further surgeries obtaining stable results in terms of symmetry. 3D printing technologies have a relevant support for a more accurate planning and surgical treatment in UCH.

Key Words: 3-dimensional, CBCT, Mandibular asymmetry, Mandibular volume, Unilateral condylar hyperactivity, Unilateral condylar hyperplasia

The unilateral condylar hyperplasia (UCH) is a pathological not neoplastic overgrowth of the mandibular condyle associated with facial asymmetry, occlusal and temporomandibular joint dysfunctions.[1] Although many theories have been suggested the etiology remains still unknown and considers trauma and genetics as possible factors. UCH mostly affects the second and the third decades and it is more common in females who are frequently affected on the right side.[2] This last evidence seems to suggest a role of the estrogens in the etiology. In 1986, Obwegeser and Makek classified condylar hyperplasia into 2 main types, hemimandibular hyperplasia and hemimandibular elongation. These presentations may occur individually or in combination as a hybrid form.[3] Nitzan et al,[4] in terms of classification system, considers a trasversal, a vertical, and a combined form.[4]

UCH diagnosis is achieved considering clinical sings and radiological imaging such as orthopantomograms (OPG), computed tomography, scans and the single photon emission computed tomography (SPECT). A correct diagnosis is also achieved examining the growth activity of the condyle and its volumetric variations, since it deeply influences the treatment options. Quantify the activity status to diagnose UCH is reached using SPECT, which enables to compare the activity status of the 2 condyles. With a difference uptake >10% between the affected and nonaffected side the patient is treated as an active UCH.[5]

At the moment there is not a clear and confirmed surgical and orthodontic treatment protocol for patients affected by UCH.[6,7] Many authors propose proportional condilectomy as the main treatment choice since it provides more stable e predictable results to achieve facial symmetry.[8,9]

Recently Nitzan[10] introduced a new approach named adaptable condylectomy which primary considers patient's occlusion.

Considered the development of 3D printing in the field of medicine the purpose of this study is to evaluate whether this technology can provide additional details to the 3D virtual planning in use for the treatment of patients affected from UCH.

PATIENTS AND METHODS

This clinical report considers 2 cases of UCH treated at the Department of Maxillo-Facial Surgery at Policlinico Umberto I in Rome in 2018.

The first patient, a 12 years' old young lady, presented at our Department concerned by her facial asymmetry. A first clinical assessment revealed a long face with a concave profile, monolateral left cross-bite, and shifting of the mandible middle line to the left. The medical history did not show any previous significant medical events. By the time she presented at our department she had already been treated orthodontically, but any result was reached because of the progressive lateral growth of the mandible (Fig. 1).

The second patient, a 17 years' old boy, presented at our department complaining about a noticeable facial asymmetry associated with lateral deviation of the chin (Fig. 2).

The diagnosis of UCH was achieved by clinical and radiological evaluation (CTCB and SPECT).

Clinical assessment valued chin deviation, dental midline, occlusal canting, cross-bite, and open-bite.

The treatment plan was conducted focusing on the millimetric discrepancy in the condylar height, occlusion, and facial symmetry.

The cone beam computed tomography (CBCT) scan was elaborated using Dolphin software (Dolphin Imaging, Chatsworth, CA) and 3D virtual models of the mandible and the skull of the patient were reconstructed.

Dolphin software was also used to export the CBCT data as a SLT file that was sent to the Oral3D printer which provided the 3D printed cast model. The Oral3D printer works as a fused filament fabrication technology and uses polylactic acid filaments that are made out of biodegradable plastic, odorless, nontoxic, and ecofriendly. The printer has a layer resolution of 100 to 500 microns and positioning precision of XY:11 microns Z:2.5 micron and a maximum dimension of the printed product of $420 \times 420 \times 420$ mm.

Linear measurements were firstly performed on the 3D virtual image using Dolphin programme (Fig. 3) and then performed by the same surgeon (VV) on the 3D printed models using a hand calliper. The distances considered were the Condyle-AnteGonion, Condyle–Sigmoid Incisure, Sigmoid Incisure–AnteGonion. These measurements taken both on the virtual images and on the 3D cast models were later compared and analyzed.

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FIGURE 1. Virtual planning consisted in linear measurements taken on both the affected and nonaffected side.

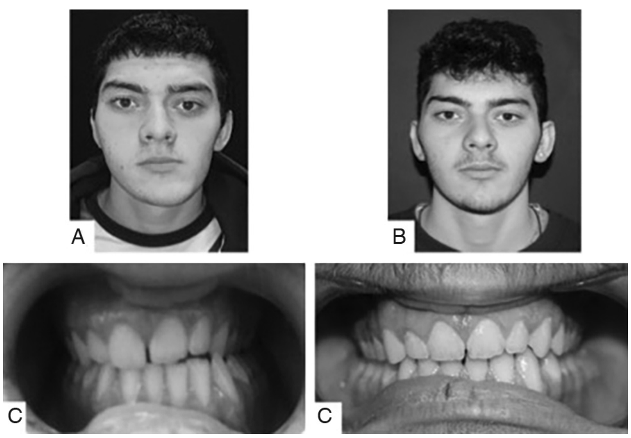

FIGURE 2. Virtual simulation of the condylectomy. (A) Virtual view of the maxillary-mandible complex before osteotomy. (B) Virtual view of the maxillary-mandible complex after osteotomy showing final occlusion.

Proportional condilectomy was then simulated either on the 3D virtual model using Dolphin software (Dolphin Imaging, Chatsworth, Calif) or on the 3D printed cast model using a hand saw (Figs. 4 and 5)

After 18 months, postoperative CBCT scan was required and new 3D cast models were printed. To evaluate whether the

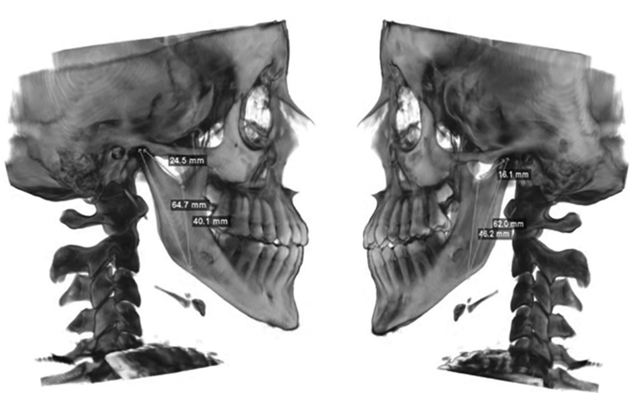

FIGURE 3. Simulation of the condylectomy on the 3D cast model.

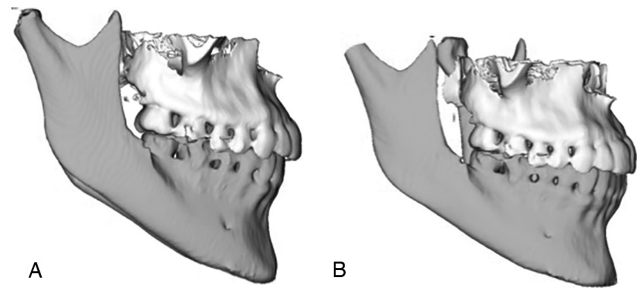

FIGURE 4. Patient 1. (A) Preoperatory clinical mandible and chin deviation; (B) clinical result after 18 months from surgery; (C) preoperatory occlusion showing the shifting of the mandible middle line toward the healthy side; (D) final occlusion after 18 months.

proportional condylectomy was effective with stable results in symmetry, the same distances considered in the presurgical planning were measured both on 3D virtual images and on 3D printed cast models.

SURGERY

Both patients underwent proportional condylectomy conducted by the same surgeon (PC). A preauricular pretragal incision was performed. After reaching the deep temporal fascia by blunt dissection, isolating and cutting the temporal vessels, articular capsule was exposed. The lateral ligament was then identified and detached 2 mm under the lateral insertion allowing the surgeon to access the TMJ inferior compartment. The head of the condyle was exposed using dedicated condylar retractors and the condylectomy was then performed using a piezoelectric device. The disk was repositioned, and lateral ligament readjusted to its anatomical level. MITEK Microfix QuickAnchor Plus 1.3 was placed into the condylar head to secure the ligament laterally.

RESULTS

At the first clinical assessment chin deviation, shifting of the dental midline and cross-bite were reported in both patients. Occlusal canting and open bite were not found in none of them.

FIGURE 5. Patient 2. (A) Preoperatory clinical mandible and chin deviation; (B) clinical result after 18 months from surgery; (C) preoperatory occlusion showing the shifting of the mandible middle line towards the healthy side; (D) final occlusion after 18 months.

The distances considered for planning condylectomy and follow-up were taken on both the 3D virtual images and the 3D cast models on the affected and the healthy sides.

Each Supplemental Table (Tab. S1–S2, http://links.lww.com/SCS/B563) shows results of the measurements of the distances Condyle-AnteGonion, Condyle–Sigmoid Incisure, Sigmoid Incisure–AnteGonion on both sides before and after surgery.

Measurements performed on the 3D cast models were both close and reliable if compared to the measurements obtained on 3D virtual images. As highlighted in the grid measurements on 3D cast model were always in excess in millimeters. The mean difference in millimeters is an excess of +0.425 mm.

At the 18 months' follow-up, none of the 2 patients needed further surgery as the symmetry and stable dental occlusion had been reached. Treatment solved chin deviation, shifting of the midline, and the cross-bite in both patients.

DISCUSSION

The UCH treatment protocol is not clearly accepted in literature because of the variety of the morphological patterns that may present to the clinician.

During the past decades surgery management for UCH has changed according the better understanding of the pathology and the development of the radiological examinations.[11]

Wolford et al in 2002 proposed high condylectomy with disc repositioning associated with orthognathic surgery as the main treatment for the active form since this protocol gives stable results compared to patients treated with the sole orthognathic surgery.[12]

An early diagnosis and treatment with condylectomy can reduce the facial asymmetrical growth that required orthognatic surgery[8] outlined the role of proportional condylectomy as the optimal treatment for UCH patients. Comparing a group of patients treated with propotional condylectomy to a group treated with high condylectomy, the former technique avoided considerably secondary orthognatic surgery.

Nowadays, proportional condilectomy is described as the better surgery protocol giving the more stable results.[9,13]

As described in literature, propotional condilectomy considers the amount of condyle to be removed as the result of the discrepancies between millimetric measurements on 2D and 3D image of the affected side with the healthy side.[8]

The 3D virtual rendering has become a fundamental instrument for an accurate diagnosis and treatment planning in UCH. 2D radiograms may not be accurate to make specific measurements for surgical planning due to the anatomical structures' superimposition, skull positioning/rotation and image magnification.[11]

Nolte et al[14] showed that OPG may be useful for the first patient screening, but not for quantification and classification of asymmetry in UCH.

Today literature confirms the primary role of the virtual 3D imaging as an important tool since it provides more details and allows the surgeon to observe anatomical structures from different angles.[14]

Studies report the 3D mirroring function, available in surgical simulator software, as a primary evaluation to calculate the amount of condyle to remove.[15] Moreover, 3D virtual images are even mentioned as useful and reliable methods in the follow-up of UCH.[16]

Recently, Nitzan has suggested "adaptable" condylectomy, an alternative approach that primary focuses on patient's occlusion. Since condylectomy is now leveled and adapted to the occlusion, this report describes how preoperative simulated planning and surgery on 3D cast models gives significant support to the 3D virtual planning in the attempt of reaching facial symmetry.

The use of editing manufacturing technology plays today an important role in oral and maxillofacial surgery especially in terms of producing surgical guides, anatomical models for the surgery planning, and the production of custom-made implants.[17]

Printed models give a significant vision of the patient's specific anatomy and help not only in surgical planning process but also in the communication with the patient.[18,19]

Furthermore, improvements of timing of operation and the surgical outcomes have been highlighted in literature.[20,21]

The reduction in surgery timing using 3D cast models is related to a more accurate planning and a less complex surgical execution compared to surgical protocols in use. Reduction in postoperative morbidity that occurs in parallel with the reduction in the complexity of surgery is also observed in other studies.[22]

Nyberg et al[23] discuss the use 3D printers' technologies in the treatment of complex craniofacial defects. In addition, it is applied for tissue regeneration, rehabilitation, and surgical reconstruction.

In this report, the authors took advantage of the 3D cast model as an additional tool in the surgery planning to previsualize the condylectomy focusing on the patient's occlusion as emphasized in adaptable condylectomy, which preserves the occlusion in case it is normal and corrects it if hyperplasia has affected it.

The 3D printed model allowed to simulate the surgery on the condyle and estimate the amount of the bone resection needed to reach the facial symmetry. It consented to predict the postoperative mandibular shape and the consequent dental occlusion with the primary contact in the molar area of the affected side and the consequent open bite of the contralateral side. The 3D model cast also helped to evaluate the eventual residual sagittal skeletal defects that may persist after condylectomy. Compared to the virtual 3D planning simulation, surgery simulation on 3D cast model gives to the surgeons a better and immediate consciousness of the mandibular movements.

CONCLUSION

3D printing technologies provide today significant support in terms of a more accurate planning and surgical treatment in UCH.

Planning simply based on the discrepancies between millimetric measurements valued either on 3D or OPG images might be no longer adequate if we challenge to adaptive condylectomy to the occlusion.

The surgeon while simulating condylectomy on the 3D model is now able to figure out immediately mandibular movements on either sagittal and transversal plane, checking occlusal contacts, becoming aware of the eventual residual defects that could need further surgeries.

As described in literature, orthodontic treatment after surgery becomes crucial to reach the final and stable occlusion since mandibular movements are deeply influenced by muscular strain. This cannot be calculated nor quantified either using 3D virtual programme or 3D cast model.

Although the financial cost of the 3D printing technologies seems to be a disadvantage,[24] 3D printed model and its use for simulated surgery represents an additional support to 3D virtual surgical planning. It is a reliable and reproducible tool that gives the surgeon more consciousness in the challenge of reaching facial symmetry.

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