Seminars in
ULTRASOUND
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Multidetector Row Computed Tomography with Multiplanar and 3D Images in the Evaluation of Posttreatment Mandibular Fractures

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Multidetector row computed tomography with multiplanar (MPR) and 3-dimensional (3D) computed tomographic reconstructions is the method of choice in condylar fractures and in the presence of complications for all types of mandibular fracture. MPR and 3D images are the best diagnostic tools to evaluate mandibular fractures after surgical treatment, both after surgery and during follow-up. The conventional radiography is imprecise in the condylar region due to the complicated anatomical bone structures in the area, the lack of sharpness, and image distortion. Computed tomographic imaging enables the assessment of joint morphology and condyle position in the mandibular fossa 3-dimensionally in the absence of superimposed interfering structures. Moreover, it could evaluate functional of temporomandibular joint thought dynamic acquisition to close and open mouth.
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The treatment of mandible fractures may be conservative or not conservative, and the management depends on the following various factors: type and location of the line of fracture, dislocation of the fragments, sex and age of the patient, edentulous/mixed dentition, and associated disorders. In general, fractures and their treatment can be divided into the 2 following groups: not condylar fractures and condylar fractures. Conventional radiography is the main imaging procedure used in the postoperative assessment of not condylar fractures. On the contrary, multidetector row computed tomography (MDCT) with multiplanar (MPR) and 3-dimensional (3D) computed tomographic (CT) reconstructions is the method of choice in condylar fractures and in the presence of complications for all types of mandibular fracture.

MPR and 3D images are the best diagnostic tools to evaluate jaw fractures after surgical treatment, both after surgery and, if necessary, during the follow-up.

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Not Condylar Fractures

The main indications for closed reduction remain controversial but may include nondisplaced or grossly comminuted fractures, fractures in the presence of mixed dentition or in the atrophic mandible, and coronoid fractures. External fixation and intraoral appliances were once widely used for closed reduction[1] but now have been largely replaced by other methods. Splints and dentures are occasionally used in children with mixed dentition or in edentulous patients. Closed reduction is generally achieved by intermaxillary fixation using arch bars, Ivy loops, or suspension screws. A recent study reported a lower complication rate with closed treatment of fractures of the mandibular body, angle, and parasymphyseal regions.[2] However, Ellis et al[3] found lower complication rates in patients with comminuted mandibular fractures treated with open reduction and fixation than with closed reduction, but costs were significantly higher.[4]

Indications for open reduction and internal fixation of mandible fractures include most symphyseal and parasymphyseal fractures (Fig. 1), and displaced body and angle fractures. A recent review by Alpert et al[5] describes the 3 basic types of rigid fixation: stabilization by compression, stabilization by splinting, and semirigid fixation. The first is based on lag screws if the fracture line is favorable and noncomminuted.[6,7] The upper screw must be placed in the buccal cortex to avoid damage to the tooth roots. Lag screws may also

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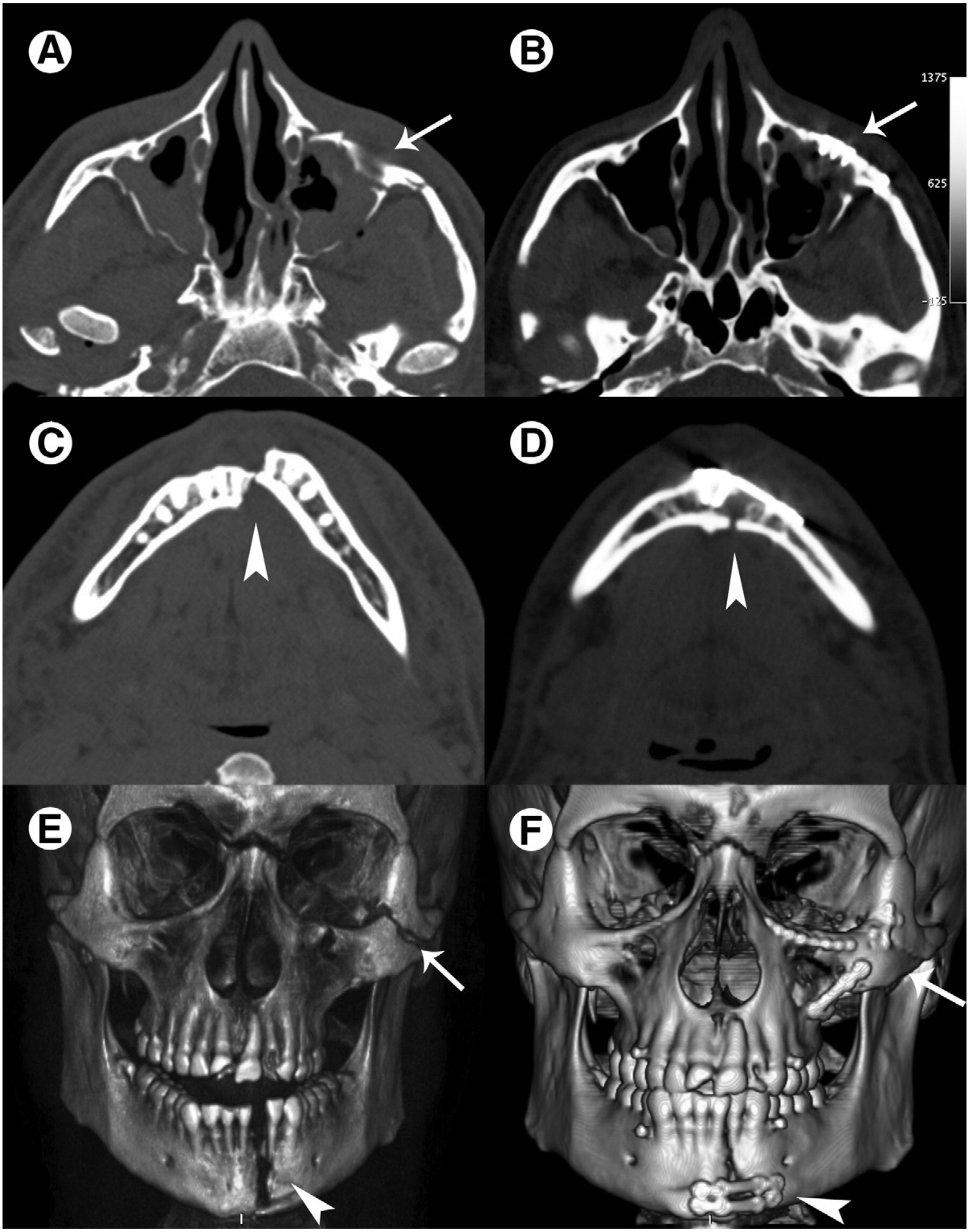

Figure 1 Left parasymphyseal (arrowheads) and right condylar fractures associated with multiple fractures of the left sinus (arrows) and other facial bones before (A, C) and after surgical treatment (B, D). 3D volume-rendering images in frontal projection show the better representation of the spatial relationships between fragments and their reduction after treatment (E-F).

be used to repair oblique fractures of the horizontal ramus. A tension band plate is sometimes placed on the superior border of the fracture line to closely approximate this area, because it tends to separate (Champy technique). The tension band plate can also be used in the wider section of the vertical mandible and is sometimes used in body and angle fractures.

The second type of rigid fixation is based on a locking reconstructing plate used when the fragments are small and comminuted, and compression is not needed.[5] Internal fixation is achieved by locking the screw to the plate rather than by compressing each fragment of bone to the plate. Semirigid fixation can be performed by using a small plate with 1.5- to

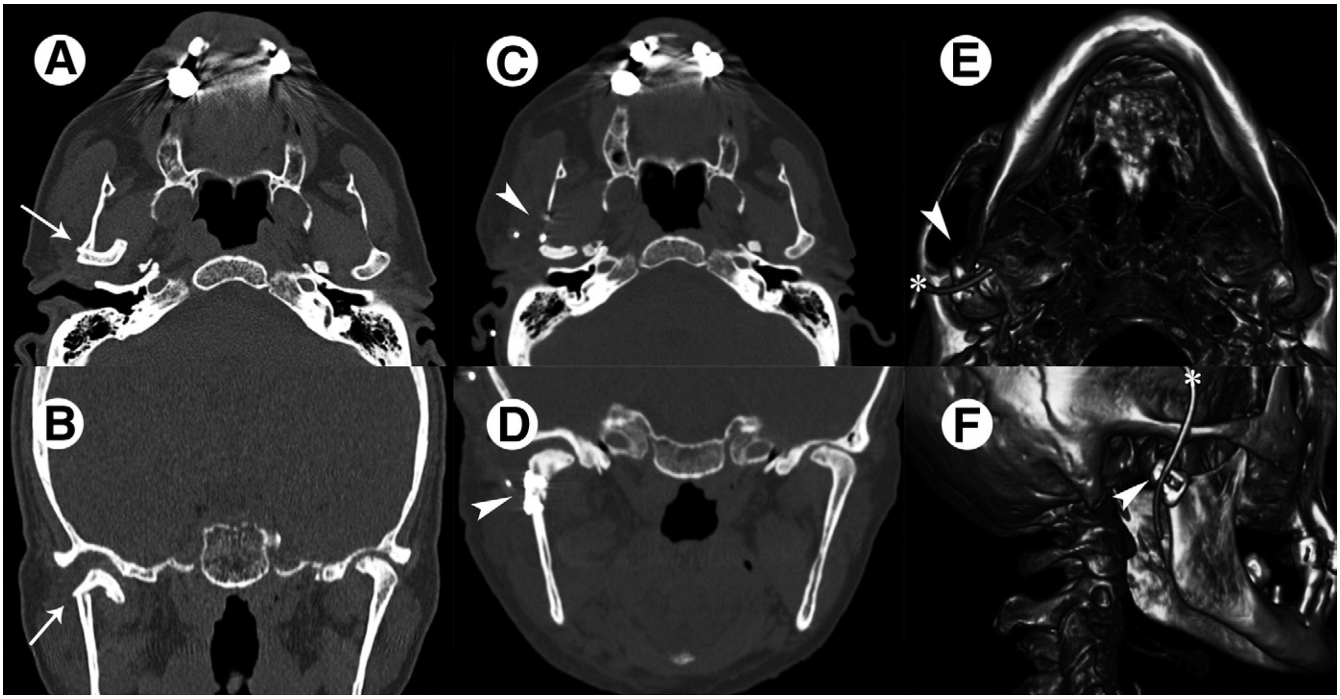

Figure 2 Fracture of condylar neck with displacement of the fragments. (A, B) The distal fragment is upper placed and the condyle is medially rotated and subdislocated (arrows). Postoperative assessment: fragments are in good position and synthesized with trapezoidal plate (arrowheads) in axial and coronal plans (C, D) and 3D volume-rendering reconstructions in axial and lateral projection (E, F). Presence of drainage (*).

2.0-mm unicortical screws. The advantage of this procedure is that it requires only limited periosteal stripping of the fracture site. This technique relies on the forces of the strong jaw muscles to "hold" the fracture in place. This procedure has a higher rate of minor complications (eg, plate/screw extrusion and rupture) than other procedures, but a low rate of major complications.[5]

Condylar Fractures

The treatment of condylar fractures, classified according to Spiessl and Schroll[8] into types I to VI based on site, displacement, and dislocation of fractures, is one of the most frequent and controversial issues of maxillofacial traumatology. There is no general consensus about indications for surgical treatment, or about the type and the techniques of containment (Fig. 2). There are a few absolute indications for open reduction and internal fixation of condylar fractures: displacement into the middle cranial fossa, impossibility of obtaining dental occlusion by closed reduction, lateral extracapsular displacement of the condyle, presence of a foreign body, or open fracture.[9] Relative indications include bilateral or unilateral condylar fractures with a midface fracture (Fig. 1), comminuted symphysis and condyle fracture with tooth loss, displaced fracture resulting in open bite or retrusion in mentally retarded or medically compromised adults who would not tolerate intermaxillary fixation, and displaced condylar fractures in the edentulous or partially dentate mandible with posterior bite collapse. Other absolute indications for open reduction of condylar fractures include patient preference (when no contraindication exists), failure of closed treatment to re-establish preinjury occlusion, rigid fixation of another facial fracture affecting occlusion, or limited stability of occlusion.[10] Absolute contraindications to open reduction are fractures at or above the ligamentous attachment (single fragment, comminuted, or medial pole) or when other injury or illness precludes extended general anesthetic risk. Other authors[11] emphasize that such clinical parameters as a good range of motion, good occlusion, and minimal pain, rather than the location of the condylar fracture, are important factors to consider when deciding whether conservative or not-conservative treatment should be performed. They recommend conservative treatment for displaced or unstable low condylar neck or subcondylar fractures.

Several studies of outcomes of condyle fractures treated by closed reduction and mandibulomaxillary fixation versus open reduction and internal fixation showed a higher percentage of complications in the closed treatment group. The most frequent complications reported for closed reduction are anatomic displacement,[11,12] asymmetry, malocclusion, reduced maximum intercisal opening, headaches, and pain,[13] impaired mastication,[14] alteration of facial morphology (shorter posterior facial height on the side of injury and more tilting of the occlusal and bigonial planes toward the fractured side).[15-18] The most frequent complications reported for open reduction are transient or permanent facial or trigeminal nerve weakness, hypertrophic or wide scars, parotid fistula, infections, osteoarthrosis, and condylar resorption (Fig. 3).

Endoscopic open reduction and internal fixation of the condylar region has been used with some success.[19-22] The

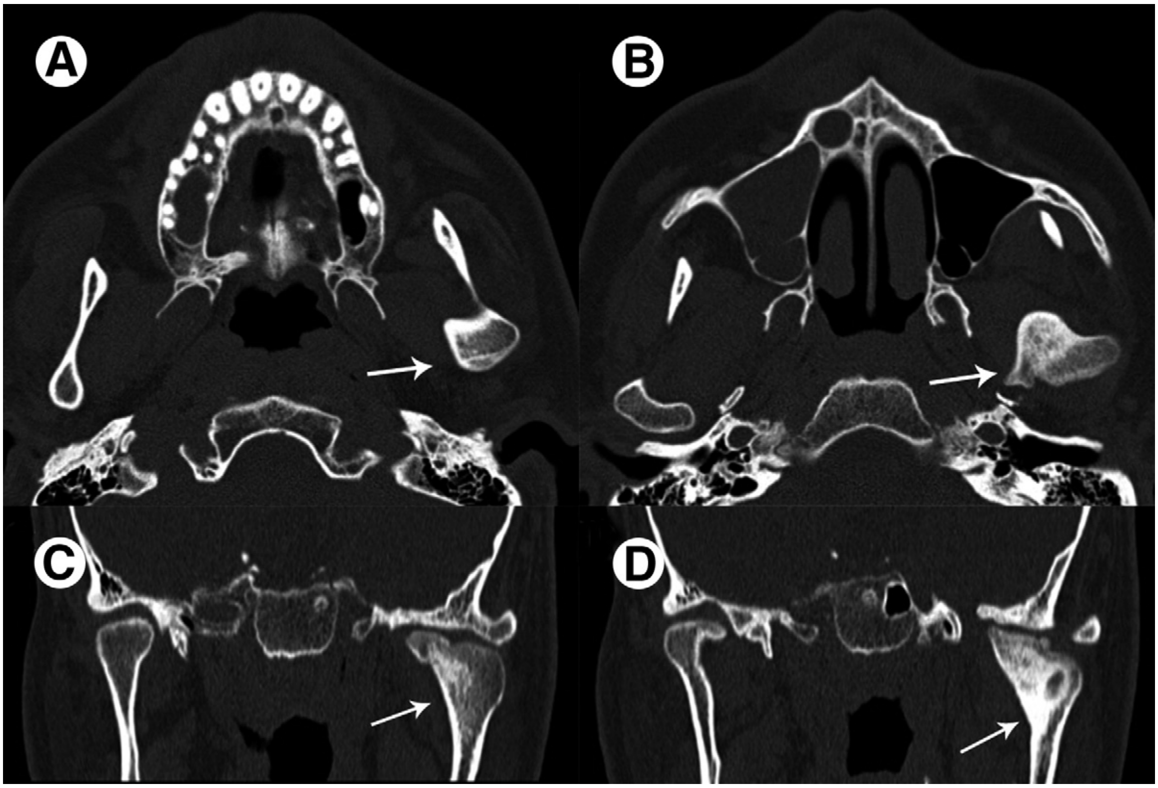

Figure 3 The axial (A-B) and coronal (C-D) MDCT images show posttraumatic deformity and sclerosis of the condyle (arrows) in follow-up after incorrect conservative treatment.

benefits of this approach are less chance of facial nerve injury and improved esthetic outcome because of smaller scars. Drawbacks to the endoscopic approach are a higher rate of hardware loosening, leading to reoperation in at least one study,[19] and a possible higher rate of nonunion, refracture,[20] and possibly malocclusion.

Complications

Mandible complication rates range from 7% to 29%.[23,24] The complication rate has been correlated to the severity of the fracture. Lois et al[25] reported a total complication rate of 9.5%, and in fractures with displacement in the range of 2-4 mm, there was no difference in the complication rate of fractures treated by closed reduction versus open reduction and internal fixation (4.3% and 5.45%, respectively). Collins et al,[26] in a retrospective study of their experience with different types of mandible fractures, reported the following complication rates: angle fractures, 9.4%; body fractures, 8%; and parasymphyseal fractures, 3.3%. There was no statistical difference between complication rates in the body and the angle. The most frequently fractured site in this study was the parasymphyseal region.[26] Alpert et al[5] described 4 types of complications, as follows: (a) those arising during appropriate treatment; (b) those caused by inadequate/inappropriate treatment; (c) those due to surgical failure; and (d) those that result from no treatment. They went on to give examples of each type of complication, namely, infection from open reduction/internal fixation, malocclusion from improper treatment, injury to the marginal mandibular nerve due to technical errors, and malocclusion from no treatment. Wound infection is the most frequent complication in all types of mandible fractures. Some authors have found that the rate of wound infection is higher in fractures treated by open reduction and internal fixation.[2] Maloney et al[27] reported a 3.3% bone infection rate in patients treated with open reduction/internal fixation. Angle fractures were the most frequent fractures in their series. Other, less frequent complications include malocclusion, nonunion, malunion, tooth loss, trismus, ankylosis, deviation, unsightly scars, and paresthesias.

Normal bony union of the mandible takes place within 4-8 weeks, depending on the age of the patient.[28] Nonunion occurs when a bony union has not occurred within this time. The radiographic appearance is one of sclerotic bony margins and a gap where the bone has not bridged the fracture site. Many of these fibrous nonunions will eventually become a bony union. Mathog and Boies[29] cited inadequate mobilization, incomplete reduction, infection, poor blood supply, and nutritional/metabolic alterations as the most frequent causes of nonunion in mandible fractures. In their series of 577 mandible fractures, the incidence of nonunion was 2.4%. Eight of the 14 nonunions were treated with debridement, antibiotics, and fixation, which suggests that improvements in technique and longer fixation periods are important factors for a bony union. Six patients required bone grafts to maintain correct occlusal relationships.[30]

Figure 4 CT measurements made in transverse (A), in coronal (B), and sagittal view. CD: the condylar distance; CL: the condylar length; CA: the condylar angulation; CS: the superior coronal joint space; AP: the angulation of the proximal fragment; S1: the superior joint space; S2: the closest anterior joint space; S3 the closest posterior joint space (S3); FD: the fossa distance.

CT Imaging

The first evaluation after treatment is by conventional radiography, which allows assessment of the initial fracture reduction and stability. CT imaging is used for a long-term radiologic analysis for condylar fractures and for suspected complications in all other locations. Patients are usually evaluated by CT imaging at 3-6 and 12 months after surgery.

CT examination requires thin collimation of slices (0.75-1 mm), 120 kV and 250 mA. The data set provides high-resolution 2D multiplanar reconstructions with contiguous 2-mm slices in the axial and coronal plane displayed in high-resolution bone window (W/L 3200:700). Additional sagittal reconstructions must be used for mandibular condylar fractures.

For these types of fractures, CT images allow us to measure many variables that have a high concordance intra- or interobserver and a low interobserver variation.[31,32] All parameters measured on the operated joints were compared with measurements on the contralateral nonfractured joints and monitored over time to give us a measure of the exact 3D reduction of condylar fractures. Symmetric position or slightly different position of the condylar process on operated joints versus the contralateral nonfractured joints indicates that it is possible to obtain anatomic restoration of condylar fractures.[33]

In the transverse plane, the parameters of evaluation are the condylar distance (distance between the condyle and the median line drawn to pass through the nasal septum and the center of the occipital foramen); the condylar length (the longest diameter of the condyle); and the condylar angulation (the angulation between the long axis of the condyle and the transverse posterior line, drawn tangentially to the posterior borders of the condyles) (Fig. 4A). In the coronal plane, the evaluable parameters concern the following: the superior coronal joint space; and the angulation of the proximal fragment (angulation between the distal and proximal fragments) (Fig. 4B). In the sagittal plane, the parameters of evaluation are the superior joint space (S1; the distance between the roof of the temporal fossa and the top of the condylar head); the closest anterior joint space (S2); and the closest posterior joint space (S3) (Fig. 4C) and the fossa distance (the distance between the most superior point on the outline of the auditory meatus and the deepest point on the outline of the glenoid fossa) to identify changes in the position of the glenoid fossa.[34]

Another important parameter is the loss of vertical height (the distance between the most superior point on the condyle and genial angle) that is a predictor for possible malocclusion, asymmetry, and neoarthrosis with the articular eminence.[35] A greater fragment dislocation is the result of a stronger traumatic impact leading to capsular rupture and scar formation.[36,37] Muscular and ligament damages with scar formation could result in reduced translation also after successful surgical repositioning. In fact, the degree of mobility of temporomandibular joint does not depend exclusively from osseous traumatic alterations.

Various groups have evaluated long-term results of condylar fractures treatment.[38-40] These groups have used only conventional X-ray film, using panoramic radiographs and Towne's view. Conventional radiographs of the condylar region is not able to identify all the possible traumatic alterations, because of the complicated anatomical bone structures in this area, a lack of sharpness, and image distortion. On the contrary, with CT imaging it is possible to assess exactly joint morphology and the position of the condyle in the mandibular fossa 3-dimensionally. MPR images on sagittal and coronal planes help to evaluate correctly spatial localization of fragments.[41,42] In detail, on sagittal images, it is possible to study the anatomical relationship between condyle and glenoid fossa, while on coronal images, the condylar axis is evaluated. These elements may contribute to determine the choice of better treatment of condylar fractures.

Moreover, the temporomandibular joint can be studied at morphostructural and functional level with CT imaging. In fact, 3D reconstruction of CT images allows a more accurate and complete assessment of the articular space. While not

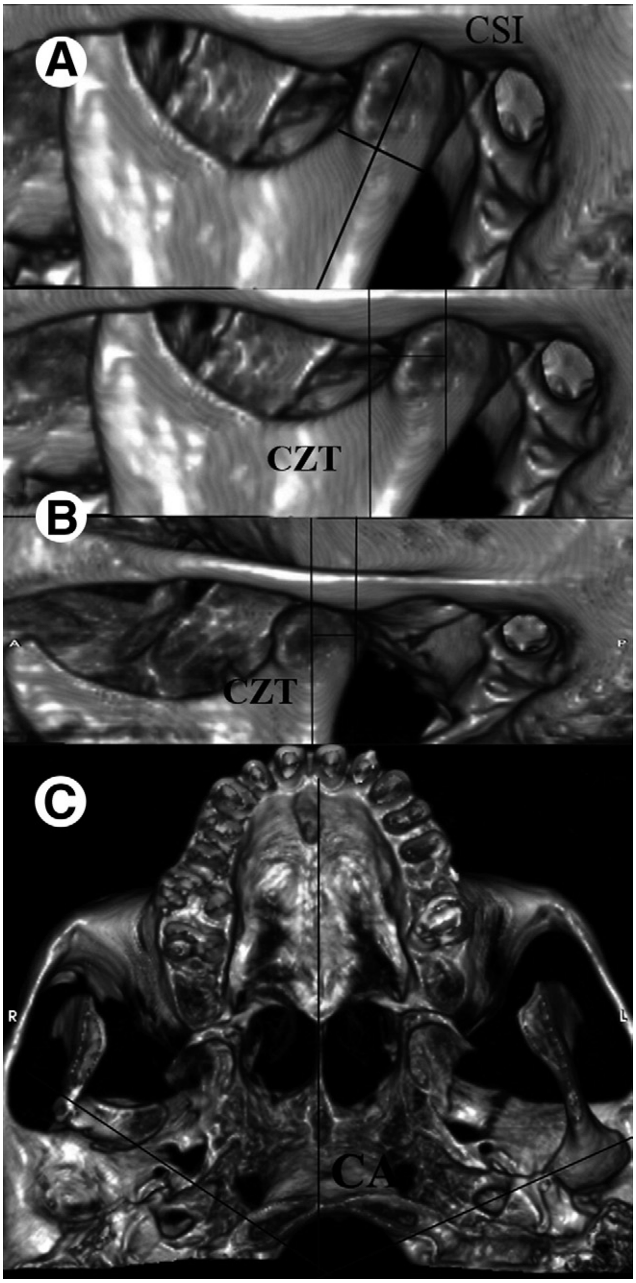

Figure 5 3D volume-rendering images allows a more accurate and complete assessment of the temporomandibular joint at morphologic and functional level in follow-up of a fractured condyle. CSI, the axis of condylar sagittal inclination (A); CZT, the distance between the condylar major axes and zygomatic tubercle, on the closed and open mouth, for the quantitative assessment of condylar movement (B), and CA, the angle of condylar twist (C). These parameters allow a quantitative assessment of the degree of mobility.

increasing the information of 2D images, this reconstruction method provides a complete anatomical picture and directly shows static and functional interactions. This examination, which has replaced the traditional stratigraphic study, is performed during mouth closing for the acquisition of morphologic and volumetric parameters and during maximum mouth opening to assess the changes of the temporomandibular joint during a dynamic phase.[43]

CT examination of the temporomandibular joint requires thin collimation of slices; the upper limit of scans is the top of the glenoid fossa and the orbital floor, and the lower limit is placed at the sigmoid notch of the jaw. To reduce the dose, the number of scans is kept as low as possible and the intensity and duration of exposure are reduced to a minimum. The lateral projection is more useful because it allows one to assess the degree of mobility fractured condyle compared with contralateral joint during maximum mouth opening and monitoring over time.[44]

The parameters most frequently evaluated are changes on the angle of condylar twist (condylar angulation) formed by median line and condylar head major axis, in the axial projection (Fig. 5A). The difference in this angle on the closed and open mouth provides a measure of mandibular rotation; the axis of condylar sagittal inclination in respect to the neck line (Fig. 5B); the distance between the condylar major axes and zygomatic tubercle, on the closed and open mouth, for the quantitative assessment of condylar movement (Fig. 5C, D). These parameters allow a quantitative assessment of the degree of mobility of a fractured condyle in follow-up after both open reduction and internal fixation and after conservative treatment.

Conclusions

The first evaluation after treatment is by conventional radiography, which allows assessment of the initial fracture reduction and stability. However, conventional X-ray film, based on the use of panoramic radiographs and Towne's view, is not able to evaluate condylar fractures, because of the complicated anatomical bone structures in this area, a lack of sharpness, and image distortion. On the contrary, with MDCT imaging, using MPR and 3D images, it is possible to assess exactly joint morphology and the position of the condyle in the mandibular fossa 3-dimensionally. MDCT is the method of choice also in the presence of complications for all types of mandibular fracture. MPR and 3D images represent the best diagnostic tools in the evaluation of mandibular fractures after every type of surgical treatment.

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