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Computer Guided Mandibular Reduction Technique Versus Conventional Technique

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Abstract— The purpose of this study was to assess the precision of computer assisted guide (CAG) for mandibular fracture reduction in comparison to the use of arch bar. **Patients and Methods:** Thirty patients with fractured mandible were included and grouped into two groups; group (I) treated by conventional method and group (II) treated using CAG. A preoperative multi-slice computed tomography (CT) scan was performed for all patients. Based on CT, three-dimensional reconstruction and virtual reduction of the mandibular fracture segments were done, and a CAG was designed on reduced inferior border and exported as Standard Tessellation Language (STL) file. The CAG was then made-up using a printing machine. Open reduction and internal fixation for the fractured segments of all patients was done. For group (I) arch bar was used to maintain occlusion while CAG was used for anatomical reduction in group (II). Postoperative CT was performed within 7 days and linear measurements were analyzed with the virtually planned preoperative reduced mandibles. **Results:** Both groups compared by measuring mediolateral measurements at three points (coronoid, lingula and inferior border) to the sagittal plane bilaterally; and measuring the anteroposteriordistancesbetween two points the lingula and pogonion bilaterally. The results showed that the treatment for CAG group was comparable to the conventional group with no significant statistical difference in linear measurements.

Conclusions:
Virtual surgical planning for displaced mandibular fractures is precise in CAG construction which helps in its preciseanatomical reduction and valuable in reducing the operative time.

Keywords: Computer assisted surgical guide**,** Mandibular Fracture**.**

Introduction

With the advance of digital technology, the possibility of superior preoperative virtual surgical planning (VSP) became a reality. Computer aided design (CAD), Computer aided manufacturing (CAM), 3D navigation and robotics have been rapidly applied and combined to be used in making precision medicine possible in maxillofacial surgery .CAD/CAM technology, together with the emerging 3D medical images based VSP technology, to maxillofacial trauma has been gaining increasing attention to maxillofacial surgeons [1-3]

Recently, maxillofacial use of VSP includes orthognathic surgery, mandibular and maxillary defects in need of reconstruction with free flaps, and complex trauma.[4, 5] This technology is intended to ease the reconstruction of various craniomaxillofacial injuries or defects, the native tissues are usually mal-positioned, injured, compromised by multiple surgeries, absent, irradiated, or severely atrophied.[6, 7] The objective of VP in oral and maxillofacial surgery is the optimization of the surgical result with regard to function and aesthetic aspects.[7]

Mandibular fractures are common facial injuries, accounting for 20%e60% of all facial fractures [8-10] and occur twice as frequently as midfacial fractures. Most mandibular fractures occur in young men, mainly between the second and third decades of life [11-13]. Routine diagnostic procedures for maxillofacial fractures comprise both CT and conventional radiography.[14]

As preoperative evaluation by three-dimensional CT with computerized simulation can aid the surgeon to decide whether open treatment is possible to fix the fracture. We have used three-dimensional simulation to assist in the planning and fabricate a surgical guide for open reduction and internal fixation (ORIF) for treatment of mandibular fractures. Therefore, the purpose of this paper was to assess the precision of computer assisted guide (CAG) for mandibular fracture reduction in comparison to the use of arch bar.

Patients and methods:

Thirty patients (8 female and 22 males, aged 15-50 years) were included in this study for open reduction and internal fixation of recent mandibular fractures. Patient selection was based on the following criteria:

- Any mandibular fracture other than subcondylar fracture were included if those fractures were recent, within two weeks from the incidence of trauma and there was no previous history of systemic disease affecting bone healing or any uncontrolled systemic disease
- On the other hand, patients with mandibular fractures with gap defects requiring bone grafting or had infected fracture or pathologic mandibular fractures site were excluded. The patients were operated at authors' institute.

All patients were virtually planned, randomly assigned by simple randomization method into two equal groups regarding to the use of CAG or not. **Group I:(Control group)** Comprised 15 patients (10 patients had one line fracture and other 5 patients had two-line fractures) mandibular fractures.

***(Siemens Sensation 64 CT scanner, Siemens AG, Erlangen, Germany)**

Group II: **(Virtually planned group)** comprised 15 patients (10 patients had one line fracture and other 5 patients had two-line fractures) mandibular fractures in which the fracture anatomically was reduced, and a **bone borne CAG**.

A signed informed consent was obtained from the patients. The study was approved by the ethical committee of Faculty of Dentistry Ain Shams University before the start of the study.

An initial clinical examination was conducted, and full detailed medical and surgical history was recorded. Thorough extraoral examination regarding lower facial contour, height, asymmetry, and any previous scarring was carried out. Also, intraoral examination was performed regarding arch form, dental occlusion, and any malocclusion or archcollapse was recorded. Intraoral and extraoral

The study procedure was explained in detail to the patients and his/her care givers. Then a signed informed consent was obtained from the patients. The study was approved by the ethical committee of Faculty of Dentistry Ain Shams University before the start of the study.

Preoperative radiological examination:

Standardized preoperative CT scans (0.5 mm pitch slices) *; was performed for each patient to assess the number and location of fracture lines, degree of displacement, and to localize the inferior dental canal or tooth in the line of fracture.

Group I:(Control group) Comprised 15 patients (10 patients had one- line fracture considered as subgroup (A)and 5 patients had two- line fracture considered as subgroup (B)) with mandibular fractures in which arch bar was used to maintain occlusion during mandibular fracture reductionthen ORIF using miniplates was done.

Group II: **(Test group)** comprised 15 patients (10 patients had one- line fracture considered as subgroup (A)and 5 patients had two- line fracture considered as subgroup (B)) withmandibular fractures in which the fracture anatomically was reduced using **bone borne CAG, which** was made-up then ORIF using miniplates was done.

***(Siemens Sensation 64 CT scanner, Siemens AG, Erlangen, Germany)**

Virtual Planning and Surgical Guide Fabrication for group II:

CT scans (bony window) of the skull were obtained .When obtaining the skull CT, the obtained digital imaging in the form of DICOM files (Digital Imaging and Communications in Medicine) were imported into Mimics Medical 19.0 software**.Then DICOM format was exported into the segmentation software (3-Matic)**. Finally, the CAG was then exported to three-dimensional printing machine*** using ‘‘Standard Tessellation Language’’ file format. Fig. (1)

**Materialise, Leuven, Belgium

***VisiJet SR 200, 3-D Systems, Rock Hill, SC

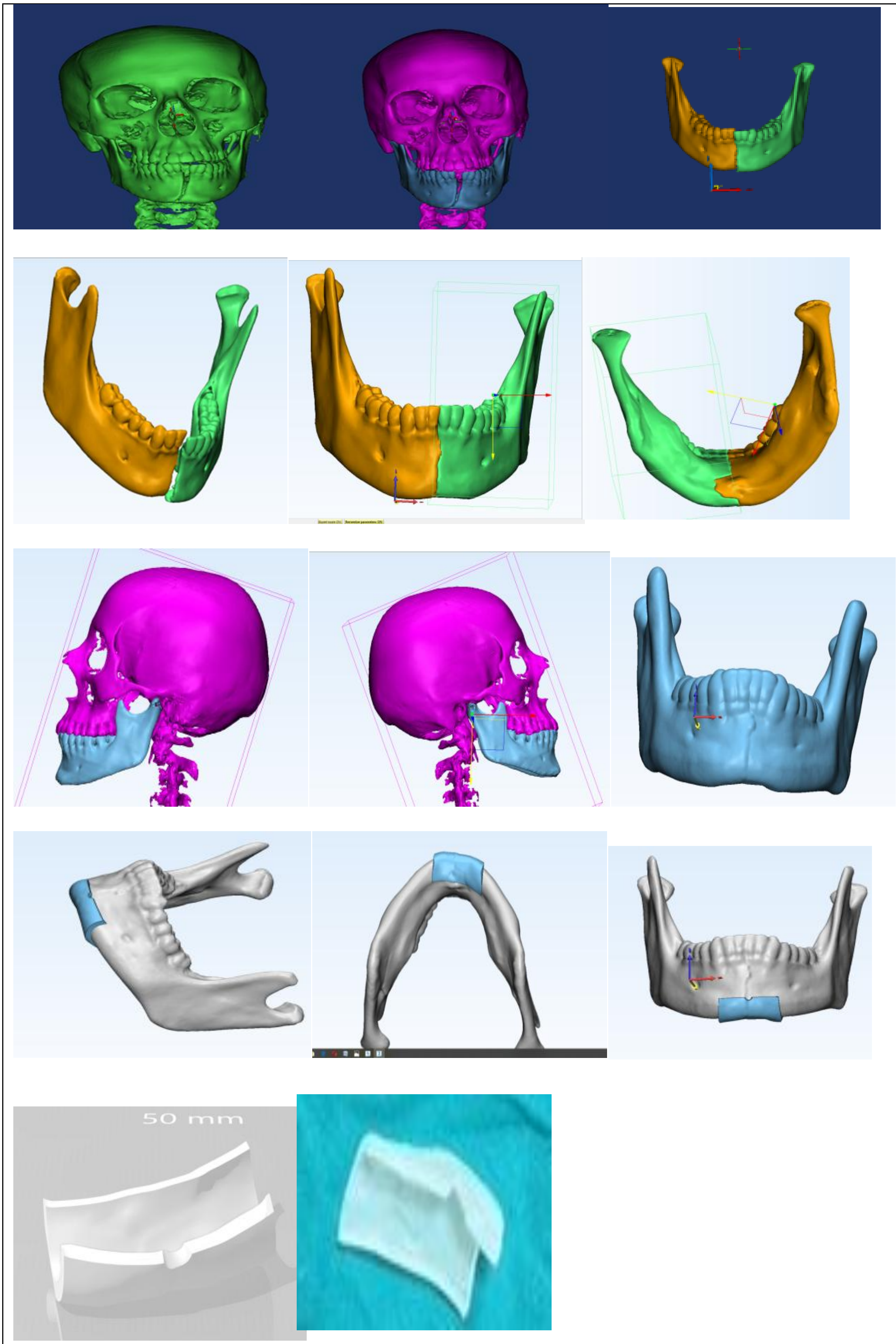


Fig., (1) Shows steps of CAG fabrication using Mimics Medical 19.0 software

Surgical technique:
All patients were operated at three to seven days after trauma (before callus maturation) under general anesthesia by nasotracheal intubation using halothane gas.

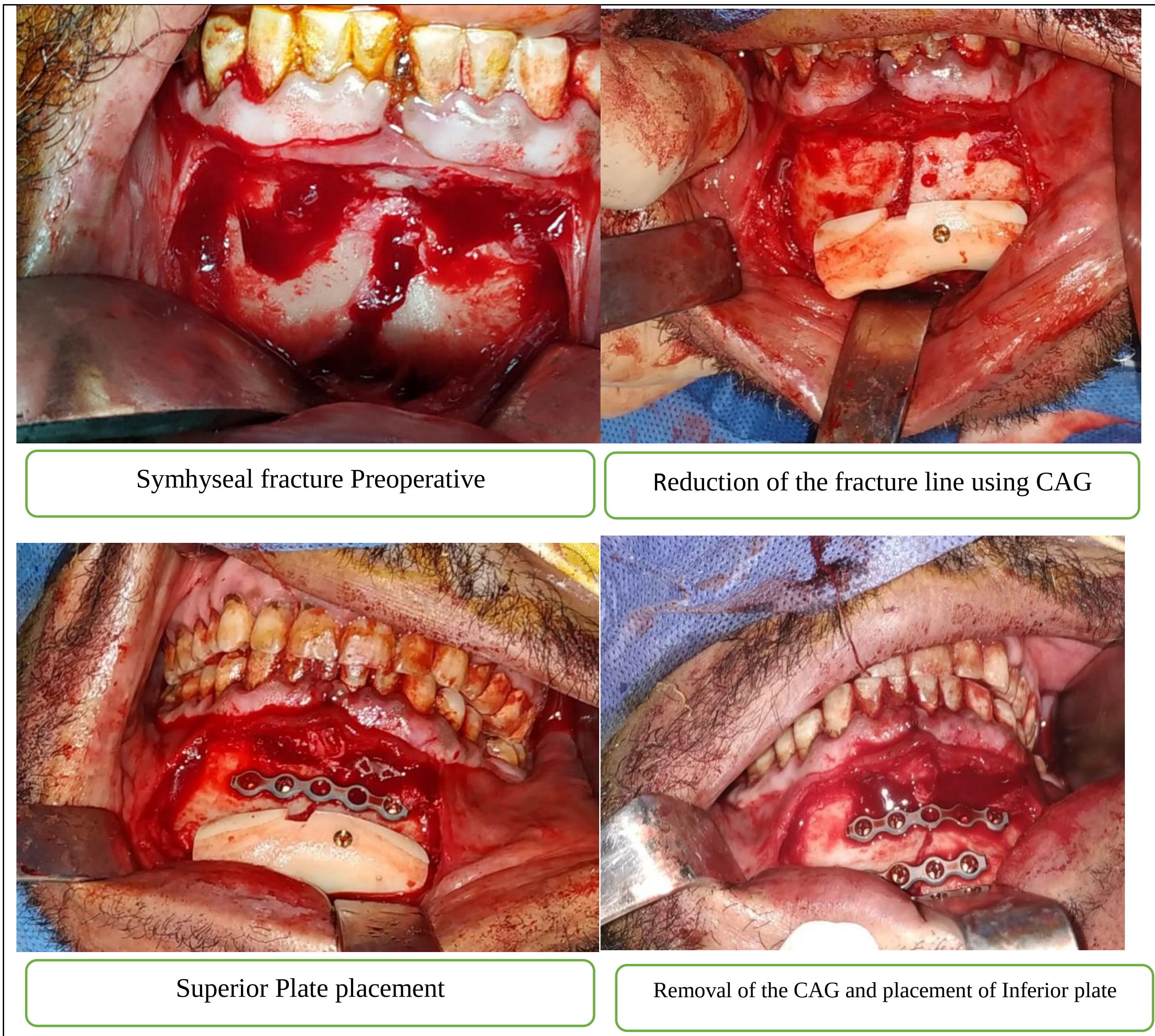
For Group I:
Upper and lower arch bars were applied first to the patient remaining dentition. Intermaxillary fixation (IMF) was used temporarily for ORIF to achieve a proper occlusion. The fracture site was accessed intraorally using vestibular incision and then subperiosteal dissection proceeded to expose the fracture line. The fractured segments were then reduced manually to the proper anatomic position and fixed using miniplates as fixation device. Finally checking the occlusion and suturing the wound using vicryl 3/0 was done.

For Group II:
The fracture site was accessed intraorally (vestibular incision), then subperiosteal dissection proceeded to expose the fracture line. After exposure of the inferior border of the mandible at the fracture site, the fractured segments were reduced to the proper anatomic position by the aid of the virtually fabricated surgical guide after its proper positioning at the fracture site and primarily fixation either by its mechanical fit or using mini screws while checking the occlusion, then placement of the superior plate was performed and this was followed by removal of the guide before placement of the inferior plate. Finally checking the occlusion and suturing the wound using vicryl 3/0 was done. Fig;(2)

After surgery, all patients were kept on antibiotics " Ampicillin Sulbactam" (Unasyn® 1.5gm/8hrs IV triple daily for five days) **** and analgesics "Ketorolac tromethamine" (Ketolac® 30mg/2ml/12hrs IV twice daily for three days) ****. All patients were dismissed one day post-operative. Soft diet was recommended for 1-4 weeks postoperatively for both groups.

****(A product of Pfizer Pharmaceutical Company, New York, USA

******A product of Amriya Pharmaceutical Industries, Egypt.



Symhyseal fracture Preoperative

Reduction of the fracture line using CAG

Superior Plate placement

Removal of the CAG and placement of Inferior plate

Fig. (2) One-Line Fracture Symphyseal fracture reduction using CAG

Clinical evaluation and follow up:

Scheduled follow-up intervals were 1, 2, 4,8 and 12 weeks postoperatively. Postoperative complications, defined as a need for further intervention, were detailed prospectively over a period of at least 6 months postoperative.

Measurement of accuracy:

To measure accuracy of reduction for both groups:

Linear measurements: Fig. (3)

A. Mediolateral Measurements:

Three mediolateral measurements were taken bilaterally right and left:

1. The first one **(Line 1)**: was the distance between the highest point on the tip of the coronoid process and the sagittal plane. It was measured by drawing a perpendicular line from the tip of the coronoid to the sagittal plane.
2. The second one**(Line 2)**: was the distance between the tip of the lingula and the sagittal plane. It was measured by drawing a perpendicular line from the tip of the lingula to the sagittal plane.

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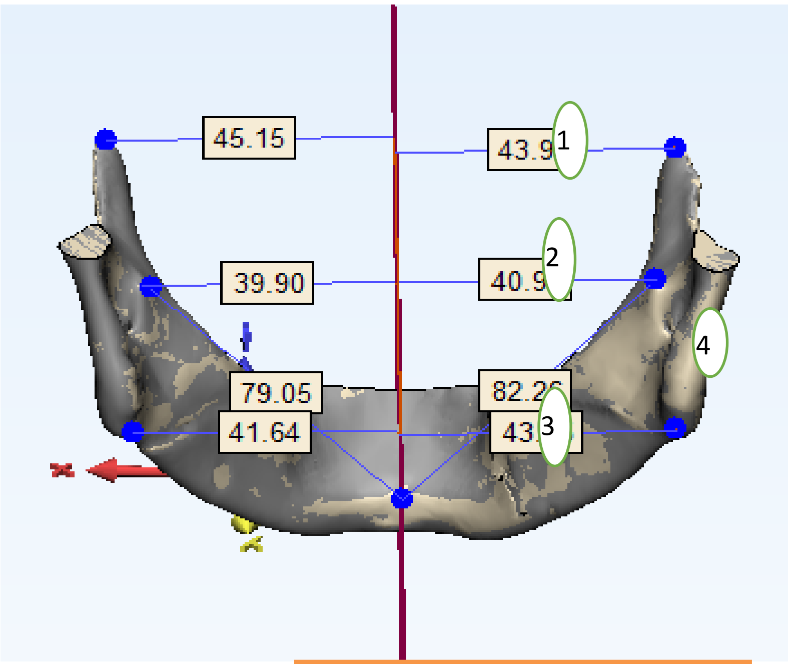
3. <u>The third one **(Line 3)**</u>: was the distance between the sagittal plane and a point in the inferior border of the mandible determined by drawing a straight line from the tip of lingula to the lowest point of the inferior border.

For standardization of the measurements, the midsagittal plane was assumed to be the plane passing through the base of the vomer and the midpoint of the clivus of sphenoid bone.

B. Anteroposterior Measurements:
The distance between the tip of the lingula and the most anterior part of the chin (pogonion) was measured as **(Line 4)**. The pogonion was identified with the help of sagittal and axial sections of the mandible.



<u>Results:</u>

The mean age of the 22 male (73.3%) and 8 female (26.7%) patients was 26.5 ±10.9 and 31.4 ±11.8 years, for group (I) and group (II) respectively. Road traffic accidents was the most common etiology for both groups (40%) for group (I) and (46.7%) group (II). While sports represent the second cause for group (I) (26.7%) and (20%)for group (II), motor vehicle accidents represent the second cause for group (II) (26.7%) and (20%) for group (I) followed by assaults which the same for both groups and represents (13.3 %). Regarding to the pattern of fracture; para-symphyseal fracture was the most common for one-line fracture pattern and represents (26.7%),(20%) for group I&II respectively, followed by symphyseal (13.3%) for group(I) and (6.7%) for group II. Right angle fracture was the same for both groups and represents (6.7%) for both groups while right body fracture was present in group II only and represents 6,7%. Left para-symphyseal and right angle was the most common of two-Line fracture and represents (20%) for group I and (13.3%) in group II, followed by bilateral para-symphyseal which was the same for both groups (6.7%) then right para-symphyseal and left angle in group I only represents (6.7%) while right para-symphyseal and left body, and symphyseal and left angle in group II only and represents (6.7%) Table(1)

Table (1): Demographic Data:

		Group I		Group II		P
Age	**(Mean±SD)**	**26.5**	**±10.9**	**31.4**	**±11.8**	**0.25**
Sex	**F**	**4**	**26.7%**	**4**	**26.7%**	**1.0**
	M	**11**	**73.3%**	**11**	**73.3%**	
Cause of injury	**Assault**	**2**	**13.3%**	**2**	**13.3%**	**0.56**
	MV	**3**	**20.0%**	**4**	**26.7%**	
	RTA	**6**	**40.0%**	**7**	**46.7%**	
	Sport	**4**	**26.7%**	**2**	**13.3%**	
Type of mandibular fracture	**Bilateral Parasymphyseal**	**1**	**6.7%**	**1**	**6.7%**	**0.63**
	Rt.Parasymphyseal +Lt.Angle	**1**	**6.7%**	**0**	**0.0%**	
	Lt.Parasymphyseal +Rt.Angle	**3**	**20.0%**	**2**	**13.3%**	
	Rt.Parasymphyseal +Lt. Body	**0**	**0.0%**	**1**	**6.7%**	
	Symphyseal + Lt.Angle	**0**	**0.0%**	**1**	**6.7%**	
	Lt Parasymphyseal	**4**	**26.7%**	**3**	**20.0%**	
	Rt Parasymphyseal	**4**	**26.7%**	**3**	**20.0%**	
	Rt. Angle	**1**	**6.7%**	**1**	**6.7%**	
	Rt. Body	**0**	**0.0%**	**1**	**6.7%**	
	Symphyseal	**1**	**6.7%**	**2**	**13.3%**	

Data expressed as mean ±SD or as frequency (Number-percent)
SD: standard deviation P: Probability *: significance <0.05
Test used: Student's t-test(unpaired) for data expressed as mean ±SD and Pearson's chi-square or Monte-Carlo when indicated for data expressed as frequency

Postoperatively, none of the patients had an infection. One patient with a mucosal wound dehiscence had to be treated with chlorhexidine mouth wash, but there were no more consequences. No hardware complications were seen in both groups. No case of non- or malunion was recorded. The function of the inferior alveolar nerve was preoperatively examined in all patients. Preoperatively, 5 patients had sensory deficits due to their injury. All patients had normal sensory function of the inferior alveolar nerve immediately postoperative except those 5 patients who were preoperatively affected regain their normal sensory sensation 2 months after surgery.

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Measurement of accuracy:

❖ **One line fracture (Subgroup A)**

A. Mediolateral Measurements

There was no statistically significant change between both groups in the mediolateral measurements.

B. Anteroposterior Measurements

There was no statistically significant change between both groups in the anteroposterior measurements. Table 2

Table (2): Showing Difference between group(I)&group (II) in One-Fracture line (subgroup A)

		Group I	Group II	P
Subgroup(A)	A-A Virtual Rt.(coronoid)	49.69±5.38	48.44±4.51	0.581
	A-A Post Rt.(coronoid)	47.56±4.22	49.45±4.11	0.323
	A-A Virtual Lt.(coronoid)	45.676±6.313	45.186±4.199	0.84
	A-A Post. Lt.(coronoid)	46.162±6.546	45.186±4.199	0.696
	B-B Virtual Rt. (Lingula)	43.03±4.13	42.07±3.15	0.569
	B-B Post. Rt. (Lingula)	42.30±4.09	42.89±2.64	0.706
	B-B- Virtual Lt. (Lingula)	38.14±4.89	39.33±3.13	0.525
	B-B Post. Lt. (Lingula)	38.56±5.13	39.26±3.21	0.72
	C-C Virtual Rt. (Inf. border)	44.49±3.86	43.62±2.69	0.563
	C-C Post. Rt. (Inf. border)	44.26±3.42	43.90±2.58	0.791
	C-C Virtual Lt. (Inf. border)	40.34±4.54	40.76±2.31	0.795
	C-C Post. Lt. (Inf. border)	40.64±4.65	40.76±2.31	0.942
	D-D Virtual. Rt. (Pogonion)	86.54±5.08	86.50±6.19	0.987
	D-D Post. Rt. (Pogonion)	87.08±5.30	86.96±6.64	0.965
	D-D Virtual Lt. (Pogonion)	86.44±5.88	84.38±7.19	0.492
	D-D- Post. Lt. (Pogonion)	86.99±6.04	84.65±7.53	0.453

Data expressed as mean±SD
SD: standard deviation   P: Probability   *: significance <0.05
Test used: Student's t-test (Unpaired)

❖ **Two-line fracture (Subgroup B):**

A. Mediolateral Measurements

There was no statistically significant change between both groups in the mediolateral measurements. Table 3

B. Anteroposterior Measurements

There was no statistically significant change between both groups in the anteroposterior measurements Table 8

Table (3): Showing Difference between group(I)&group (II) in Two-Fracture line (subgroup B)

		Group I	Group II	P
Subgroup(B)	A-A-V PreRt.(coronoid)	46`.82±1.29	47.16±2.31	0.78
	A-A-V PostRt.(coronoid)	46.82±1.29	47.16±2.31	0.78
	A-A-PreLt.(coronoid)	47.040±2.713	45.620±4.731	0.576
	A-A-PostLt.(coronoid)	47.040±2.713	45.620±4.731	0.576
	B-B-V-PreRt.(Lingula)	41.89±2.78	40.63±2.55	0.48
	B-B-V-PostRt.(Lingula)	41.89±2.78	40.63±2.55	0.48
	B-B-PreLt. (Lingula)	40.99±3.65	39.49±3.45	0.522
	B-B-PostLt. (Lingula)	40.99±3.65	39.49±3.45	0.522
	C-C- V Pre-Rt. (Inf. border)	44.35±1.62	43.00±2.90	0.389
	C-C- V Post Rt. (Inf. border)	44.35±1.62	43.00±2.90	0.389
	C-C- PreLt. (Inf. border)	44.13±5.44	42.01±3.50	0.486
	C-C- PostLt. (Inf. border)	44.13±5.44	42.01±3.50	0.486
	D-D- V PreRt.(Pogonion)	77.70±6.31	85.41±5.49	0.073
	D-D- V PostRt.(Pogonion)	77.70±6.31	85.41±5.49	0.073
	D-D-PreLt. (Pogonion)	76.93±5.81	84.64±5.59	0.065
	D-D- PostLt. (Pogonion)	76.93±5.81	84.64±5.59	0.065

Data expressed as mean±SD
SD: standard deviation P: Probability *:significance<0.05
Test used: Student's t-test (Unpaired)

Discussion:

Virtual Surgical Planning (VSP) in the field of maxillofacial trauma offers the ability to replicate full anatomic models, and to fabricate surgical guides and custom plates. These evolutions have become a precious tool for oral and maxillofacial surgeons. Currently, VSP in the field of trauma is fast and user-friendly.[15-17]

Numerous studies that treat CMF fractures perform mirror imaging of the contralateral un-fractured side for reconstruction of the affected side. In the current study, we rather did segmentation of the fractured bone segments and then virtual reduced them to obtain the pre-injury anatomical contours. Then surgical guide was fabricated on the virtually reduced mandible. [18-21]

The surgical guide was strong enough to reduce the fractured mandible to its virtually planned position until the hardware was applied. Also, the material used to fabricate the surgical guide was stable at normal body temperature and was non-absorbable to fluids. Therefore, it did not lose its strength nor deform when be autoclaved or when in contact with blood and body fluids.

The lengths of the surgical guide were 15mm anteroposterioly and the height ranged between 8 and 10mm, which was enough to allow proper fitness for perfect reduction. These dimensions of the guide did not require longer incisions or extensive periosteal striping because these dimensions neither exceeded the anteroposterior length of the used plates nor the distance between the upper border of the inferior border plate and the upper border of the superior plate.

As computed tomography (CT) has become a routine diagnostic tool in the management of maxillofacial trauma. Also, CT is the imaging modality of choice when assessing a traumatic mandibular injury and can demonstrate 100% sensitivity in detecting a fracture. This is through use of a multislice CT, which produces accurate coronal and sagittal reconstructions. So we used multislice CT scans (bony window) of the skull in our study.[22, 23]

This study was a quantitative comparison of the treatment of mandibular fractures either using the CAG or the conventional technique. The results showed that the treatment for the CAG group was comparable to the conventional group with no significant statistical difference in linear measurements.

CONCLUSIONS:

- Virtual surgical planning and model design have given us the ability to visualize the surgery before it occurs, design the desired outcome, provide guides for performing the surgery, and furnish tools for confirming the match between the planned and desired outcome.
- Computer assisted surgical guide aided in obtaining accurate anatomical reduction of the displaced fracture segments of mandibular fractures.
- Computer assisted surgical guide has become a useful adjunct to treat acute mandibular fractures.

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