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Precision of Proximal Segment Repositioning Using Digitally Planned Custom Made guide in Sagittal Split Ramus Osteotomy

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Abstract

Background: Orthognathic surgery is widely used surgical procedure. The most common used orthognathic surgical procedure is bilateral sagittal split osteotomy (BSSO) that is used for managing skeletal mandibular excess, deficiency or asymmetry.
Objective: To correct functional and aesthetic problems.
Patients and Methods: A total of (12 patients) 24 condyles have been included in our study all with cl II malocclusion, open bites and asymmetry, both genders males and females, their age ranges between18 to 40 years, all the cases had preoperative and postoperative CT scans.
Results: By comparing pre and post operative CT scans regarding condylar positions for both groups. The results revealed that there was less movement of condylar head in group with device and direction of movement was more favorable.
Conclusion: This study showed that the Digitally Planned Custom Made guide was useful in repositioning condyles with minimal movement post operatively and more favorable direction of movement.
Keywords: Orthognathic surgery, condyles, CADCAM guides, sagittal split ramus osteotomy, proximal segment

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Introduction

Orthognathic surgery is the art and science of diagnosis, treatment planning, and execution of treatment by combining orthodontics and oral and maxillofacial surgery to correct musculoskeletal, dento-osseous, and soft tissue deformities of the jaws and associated structures that is first pioneered first by Hugo Obwegeser and published internationally in 1957 . the two commonly used mandibular orthognathic surgery includes intraoral vertical ramus osteotomy (IVRO) and sagittal split ramus osteotomy (SSRO). Both IVRO and SSRO have the potential for postoperative condylar displacement [1].

Bilateral sagittal split osteotomy (BSS0) is an orthognathic surgery used either with or without upper jaw surgery to treat mandibular deformity for correcting mandibular prognathism, retrognathia, and asymmetries. It was first described by Trauner and Obwegeser in 1957. Soon many modifications had been suggested by Dal Pont (1961), Hunsuck (1968), and Epker (1977). Since then, this valuable technique has become an important cornerstone of maxillofacial surgery. Despite the routine nature of bilateral sagittal split osteotomy for most oral and maxillofacial surgeons, a wide range of complications exists, such as unfavorable fracture (bad splits), infection, neurosensory disturbances of lower lip, and relapse [2-9].

Our study focuses on postoperative immediate relapse after BSSO, which has been mainly caused by improper positioning of the mandibular condyles in the glenoid fossae which also causes multiple undesirable effects, such as internal derangement of the TMJ, condylar sagging, [10,11] whereas delayed relapse was due to unstable occlusion, condylar resorption and inadequate fixation.

One of the most challenging problems of BSSO is preserving pre-operative condylar position in a glenoid fossa in centric relation passively, to get more accurate and stable results and a better temporomandibular joint TMJ function and preventing condylar resorption [12] condylar position can be changed in BSSO due to supine positioning of patient or effects of muscle relaxant drugs, or applying pressure by IMF without correct positioning of condyles in centric relation. [13].

Condylar-repositioning techniques and equipment have been documented, although their effectiveness and need are still debatable. The previously described techniques for repositioning the proximal segment may be divided into four categories: navigation, stiff retentions [20, 15, 16], sonographic monitoring, and manual techniques [14] [18, 19].

In 1976, Leonard [20] made his initial effort to fix the condylar position by utilizing a proximal segment-orienting device. Polley and Figueroa [22] used a set of detachable guides attached to the occlusal guide after Savoldelli *et al.* [21] made a skeletal guide fixed temporarily on each arm with screws to prevent movement during the guided osteotomy, but due to the time and expense added to the procedure, complexity, and cost of many of these techniques, surgeons preferred manual methods relying on manual positioning of the proximal fragment intraoperatively and visual inspection of the superior and inferior borders of the osteotomy during fixation [23,24].

With the increasing popularity and recent advancements in computer-assisted designed and computer-assisted manufacturing (CAD-CAM) technology and virtual surgical planning (VSP), improvement in pre-surgical planning was seen and proved highly accurate compared with standard methods [25, 26]. Reconstructive surgery has been easily guided by the use of intraoperative 3D printed surgical guides [27, 28].

The aims of BSSO or any orthognathic surgery are Aesthetic, function, and stability [29], and to our knowledge, there are few studies on using 3D printed surgical guides for positioning condyles intraoperatively and preserving condylar stability after surgery. Therefore, our present study is done to focus on and evaluate the effectiveness of VSP and CAD-CAM guide made from polyethylene for reproducibility of original condyle position and postoperative stability in the bilateral sagittal split osteotomy. The aim of this study is to investigate the use computer generated guide for maintaining condylar position during bilateral sagittal split osteotomy.

Patients and Methods

A total of (12patients) 24 condyles have been included in this research, their ages ranged between18 to 40 years, males and females were included.

All the patients planned to have a sagittal split ramus osteotomy, and all surgeries were done in Sulaymaniyah Surgical Teaching Hospital-Maxillofacial Surgery unit from September/2021 to May/2022. All patients had facial deformities of Cl III skeletal and dental relation.

Inclusion criteria: adult patients with Cl III skeletal and dental relation.

Exclusion criteria: Deformities due to trauma, Patient operated previously for facial asymmetry, previous orthographic surgeries, and patients who had esthetic fat and fillers procedures.

Following a discussion of the benefits and drawbacks of the surgical intervention and in accordance with a protocol authorized by the institutional review board, written consent was acquired from each patient after they had been told about the research procedure and surgical risks. Clinical images, cephalometric analysis, stone and digital laser-scanned dental models, CR bite registration in an upright posture, and possible surgery were all performed as part of the routine orthogenetic workup.

All the cases had preoperative CT scans with the patient in the supine position and centric relation bite with the condyles in the glenoid fossae and postoperative CT for comparing the condylar head movement within the glenoid fossae. The accepted CT scan had the following criteria:

1. Mandible condyles, glenoid fossa, maxilla, zygoma, and orbital bone were included in the radiological field.
2. Jaws are in centric occlusion during scanning.
3. Acceptable quality without major artifacts.

The CT Scans were taken with exposure as closely as possible at 140kV and 120 MA with 1mm slice thickness. The scans were burned on a DVD in Digital Imaging and Communications in Medicine (DICOM) format, then data were analyzed and 3D reconstructed using Radio-Ant DICOM View .Figure (1), the 3D converted data saved as STL (standard triangle language)Style files were imported into Materialize 3-Matic 21 (materialize the USA) Figure (2), Guide was created using the design module. Finished 3D models of the guides were printed using Form 3B (Formlabs, USA) with biocompatible resin and washed and cured using Form Wash and Form Cure (Formlabs USA) respectively while adhering to the biocompatible protocol as suggested by the manufacturer Figure (3).

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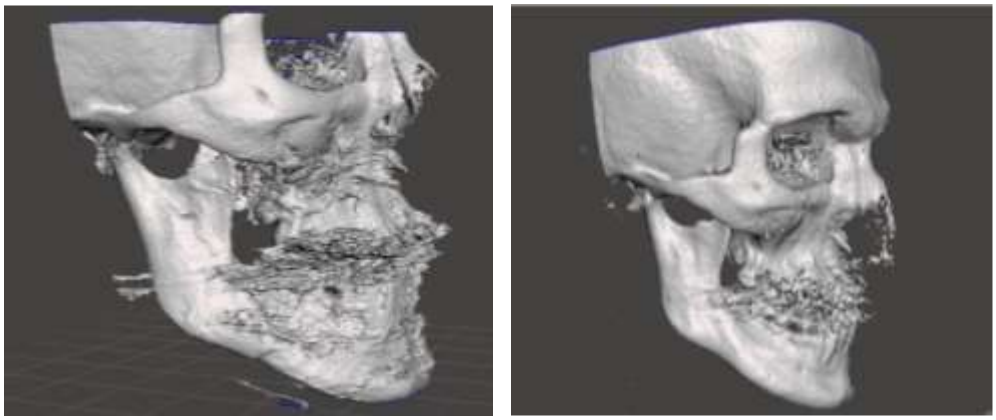
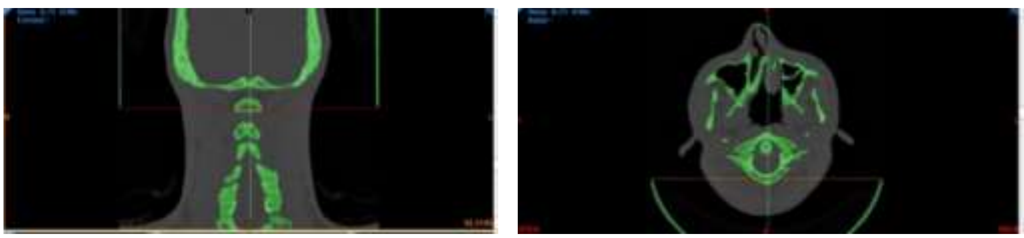


Figure (1): a: 3D Ct scan before removing and cleaning artifacts
b: Cleaning artifacts from the 3D reconstructed CT scan, removing unnecessary data in mesh mixer using cut and Boolean tools



a: coronal view b: sagittal view

c: transverse view d: 3D reconstruction view

Figure (2): Landmark identification and segmentation in mimics; CT scan segmentation converting DICOM to STL files

The guide was constructed with sufficient anatomic precision without excessive extensions, with its double arms adhering proximally to the external oblique line at the anterior border of the ramus and distally to the zygomatic bone. The design considers that it should be out of the surgical cut ,and shouldn’t be armrd on the mobile part of the jaw after osteotomy, nor positioned on area of plate fixation.

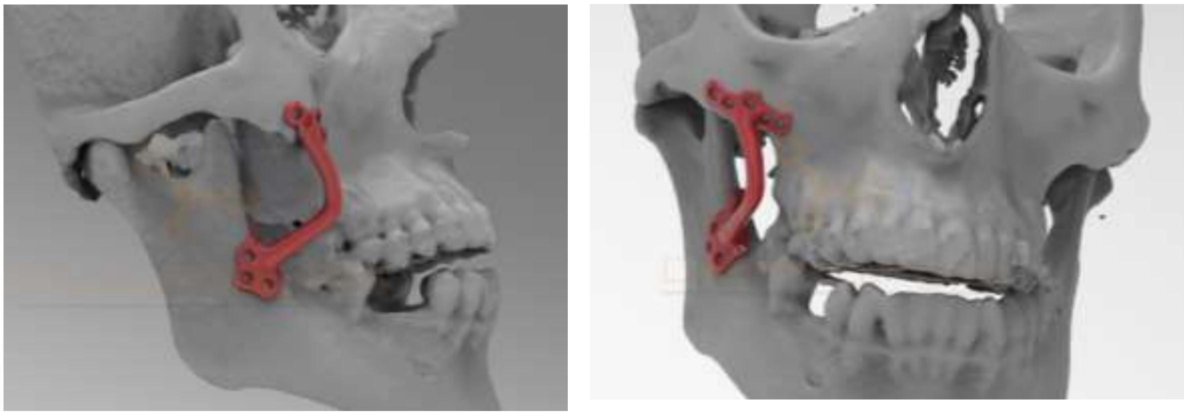


Figure (3): Guide design that have a double-arms adhering to the external oblique line at the anterior border of the ramus and distally adherent to the zygomatic bone

Surgical procedure

All surgeries were done under general anesthesia and all patients had maxillary lefort 1 advancement and bilateral sagittal split osteotomy and mandibular set back through a standard intraoral vestibular incision just lingual to the external oblique ridge, halfway the mandibular ramus superiorly to mesial of the second molar inferiorly with sub periosteal dissection to expose mandibular ramus, for maxilla vestibular incision made extending from left to right first molars with dissection to expose the maxilla entirely and zygomatic bone.

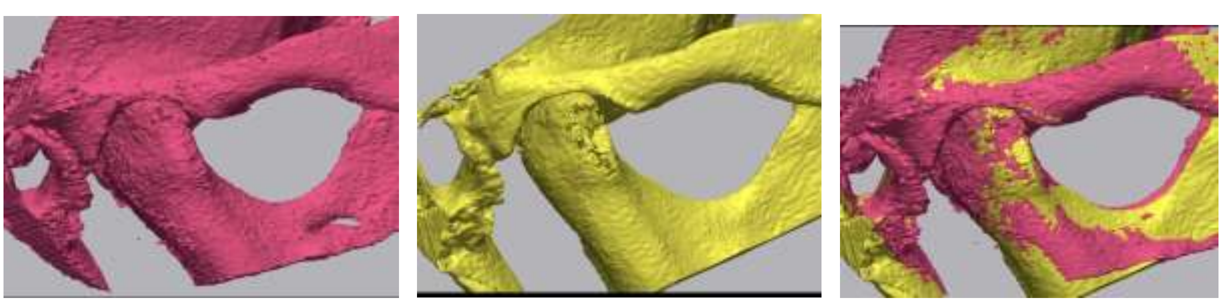
The preoperative designed guide was placed accurately to be with close contact with the anterior border of ramus and zygomatic bone when teeth are in centric occlusion and theses points were used as a fixed reference point not affected by the maxillary cut. Figure (4), A 1.5 mm drill was used to drill holes for the positioning screws through the guide at the predetermined positions through both the proximal and distal parts fixed with 2mm monocortical screws with upper and lower jaws on intermaxillary fixation, the guide is then removed. The osteotomies were completed for both the mandible and maxilla. The guide was fixed again to previously drilled holes, now the guide is holding the proximal segment in the same preoperative planned position and the distal segment in new positions, maxilla-mandibular fixation was done and the proximal and distal segments are fixed by biochemical 2mm screws and 4 hole titanium plates. Then the guide and intermaxillary wires was removed, occlusion compared to planned occlusion, and suturing was done with running 3.0 Vicryl running sutures.

Figure (4): Intra operative guide placed accurately to be with intimate contact with the anterior border of ramus and zygomatic bone when teeth are in centric occlusion

Postoperative scan CT was done between days 3 to 7. Pre and post-CT and scans were burned on a DVD in digital imaging and communications in medicine (DICOM) format and the data was, analyzed and 3D reconstructed using the RadiAnt DICOM Viewer v. 2020.2.3 (Medixant, Poland). For each patient, the scan data was segmented two times, for pre and post-operative scans.

The three-dimensional data was exported with the same software and saved as STL (Standard Triangle Language) files using the hires option. The stereo lithographic files then were refined using Mesh mixer v3. 5 (Autodesk, Inc. USA). The refinements included fixing mesh holes, spikes, and foreign body artifacts when present [30].

Then pre and post-operative CT scans were aligned using best-fit alignment and compared using the root mean square deviation (RMSD) algorithm in Geomagic Control X v2018 1.1 (3DSystems Inc., USA) and also compared the condylar head movement in anterior, posterior, medial, lateral direction Figure [5, 6].



a: b: c:

Figure (5): a: Pre-operative CT scan. b: post-operative CT scan. c: Pre and postoperative CT scans aligned using best fit alignment

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ORIGINAL RESEARCH
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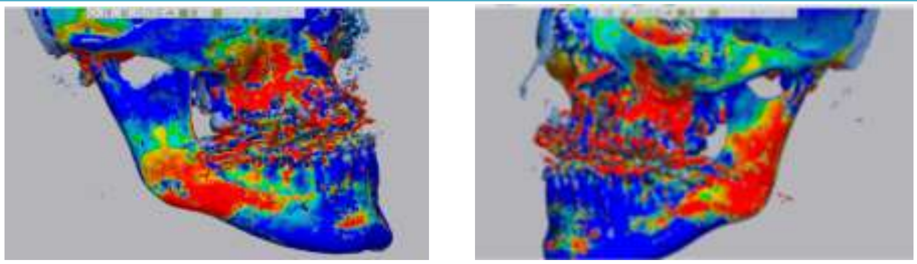

Figure (6): Pre-operative CT scan and postoperative CT compared using RSMD algorithm in geometric control x (a: left side b: right ide)

Pre and post-operative data was automatically aligned is a common numerical calculation to compare two solid structures by aligning them in a way that there is a minimal distance between each of their corresponding surface points. According to the literature, the advantage of this method is that it is algorithmically driven and lacks human interference and therefore it is free of operator errors during alignment [31].

Statistical Analysis

Data was collected and coded. The collected data was reviewed and analyzed using the Statistical Package for Social sciences (SPSS version 23). Descriptive statistics such as frequency and percentage was calculated. Measures of central tendency and dispersion around the mean were used to describe continuous variables. Moreover, in order to compare the results of the two continuous variables to measuring, the correlation was used for determine the correlation between two variable. P value was obtained for the continuous variable using Independent Samples Test and ANOVA for comparing mean and was considered significant if it was less than 0.05.

Results

Pre and postoperative measurements of the condylar position in the anterior, posterior, medial, lateral planes and using RMSD method done based on criteria explained in the materials and methods. The Superimposition of the post- and pre-operative CTs for the 12 patients (24) condyles revealed differences in amount of movement between measurements of the patients with pre-fabricated guides and those without guides. The measurements were conducted by two methods; RSMD and by measuring condyle position by comparing it to preoperative position in anterior, posterior, medial and lateral directions as discussed previously in material and methods. All the surgeries done were set back of mandible and maxillary advancement, the direction of movement was highly similar for both groups, 12 condyles (6 patients) moved in anterior medial direction, 8condyles (4 patients) moved in anterior lateral direction] both of the patients had asymmetry in frontal view with mandibular prognathism], and the other 4 condyles (2 patients) moved in posterior lateral direction. In comparing pre and post operative CT scan in medio-lateral direction, the condylar displacement was the same 12 condyles moved medially and 12 moved laterally, with no statistical difference this reveals that guide placement had not effect on direction of condylar displacement Table (1).

Table (1): Measurements of the amount and direction of condylar head movement in both groups first 6 results with guide last 6 results without guides

Patients	The net Direction of movement	RMSD		Anterior		Posterior		Lateral		Medial	
		RT	LT	RT	LT	RT	LT	RT	LT	RT	LT
with guide	Anterior medial	0.8	0.78	-2.47	-1.64	+2.06	+2.09	+2.21	+2.72	-2.58	-2.37
with guide	Anterior medial	0.77	0.8	-2.40	-1.7	+1.97	+1.89	-2.13	-2.45	+2.43	+2.21
with guide	Anterior lateral	0.74	0.79	-1.49	-1.95	+1.54	+2.40	+2.96	+1.81	-2.22	-1.24
with guide	Anterior medial	0.81	0.79	-2.46	-1.63	+2.05	+2.07	+2. 19	+2.71	-2.56	-2.35
with guide	Anterior medial	0.79	0.82	-2.42	-1.6	+1.97	+1.86	-2.15	-2.44	+2.45	+2.19
with guide	Anterior lateral	0.75	0.78	-1.49	-1.94	+1.55	+2.41	+2.95	+1.82	-2.21	-1.24
without guide	Anterior medial	1.62	1.34	-3.54	-4.56	+3.20	+2.76	+3.62	+2.88	-2.30	-3.38
without guide	Anterior lateral	1.33	1.64	-4.71	-4.45	+3.71	+2.86	-3.00	-4.25	+5.01	+3.06
without guide	Posterior lateral	1.55	1.44	+2.01	+2.46	-4.48	-4.70	-2.23	-3.07	+3.51	+2.02
without guide	Anterior medial	1.64	1.32	-3.55	-4.55	+3.21	+2.75	+3.63	+2.89	-2.29	-3.39
without guide	Anterior lateral	1.32	1.65	-4.72	-4.44	+3.70	+2.87	-3.00	-4.25	+5.00	+3.07
without guide	Posterior lateral	1.54	1.45	+2.02	+2.47	-4.47	-4.71	-2.24	-3.08	+3.52	+2.01

*(+) direction of movement means, condylar head movement in medial and anterior direction
*(-) direction of movement means condylar head movement in lateral and posterior direction

Figure (7) depicts the results of measuring condylar movement by root-mean-square deviation (RMSD). As revealed by this figure, the group with guide devices experienced smaller condylar movement (RMSD<1.0), while the group without guides had larger condylar movement (RMDS≥1.5)

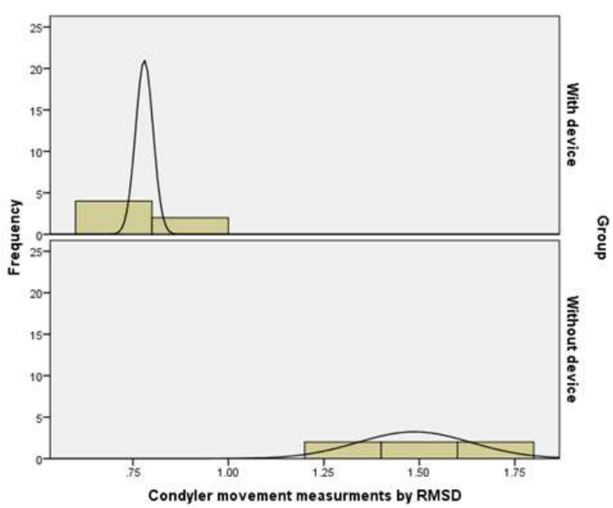

Figure (7): Comparisons between the amount of displacement in the condylar head postoperatively, minimum amount of displacement occurred in group when the guide was used, and significantly larger amount of displacement encouraged in group where device was not used

To measure the amount of the displacement of the condylar head, comparing the two groups regarding their condylar position after the surgery revealed that there was a significant difference between them in amount, measured by the root-mean-square

ORIGINAL RESEARCH
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deviation (RMSD) of their right condyles ($p<0.001$), such that those with guides had less displacement of condylar head than those without guides (0.77±0.03 versus 1.50±0.16 mm). The two groups were also significantly different regarding the RMDS of their left mandibles ($p<0.001$), the measurements in the group with guides was 0.79±0.01 mm, while that of the group without guides was 1.47±0.17 mm Table (2).

Table (2): One-sample T-test statistical analysis of the condylar position changes in the two groups

	Group	N	Mean ± SD	95% Cl	P-Value
RT (RMSD)	With device	6	0.77±0.03	-0.10 – -0.46	<0.001
	Without device	6	1.50±0.16	-1.12 – -0.34	
LT (RMSD)	With device	6	0.79±0.01	-0.95 – -0.42	<0.001
	Without device	6	1.47±0.17	-1.09 – -0.27	
RT Anterior distances (mm)	With device	6	-2.12±0.55	-5.88 – 5.80	0.99
	Without device	6	-2.08±3.60	-8.71 – 8.64	
RT Posterior distances (mm)	With device	6	1.86±0.28	-6.32 – 8.40	0.73
	Without device	6	0.81±4.58	-10.28 – 12.37	
RT Medial distances (mm)	With device	6	-0.79±2.79	-10.50 – 4.76	0.36
	Without device	6	2.08±3.85	-10.80 – 5.06	
RT Lateral distances (mm)	With device	6	1.01±2.75	-5.75 – 8.85	0.59
	Without device	6	-0.54±3.63	-5.96 – 9.06	
LT Anterior distances (mm)	With device	6	-1.76±0.16	-6.04 – 6.86	0.88
	Without device	6	-2.17±4.02	-9.56 – 10.38	
LT Posterior distances (mm)	With device	6	2.13±0.26	-5.15 – 8.80	0.54
	Without device	6	0.30±4.34	-8.91 – 12.56	
LT Medial distances (mm)	With device	6	-0.47±2.39	-7.77 – 5.71	0.69
	Without device	6	0.56±3.46	-8.13 – 6.07	
LT Lateral distances (mm)	With device	6	0.69±2.76	-5.39 – 9.74	0.47
	Without device	6	-1.48±3.83	-5.70 – 10.05	

Comparing the two groups regarding right and left condylar head movement indicated that the group without guide devices experienced more right and left condylar movement than the group with guide devices. As indicated in Figure (3), the mean right condylar head movement in the group with devices was <.77, while it was 1.5 in the group without guides. Also, the mean left condylar head movement in the group with devices was <.79, while it was 1.473 in the group without guides Figure (8). In terms of the direction of condylar head movement, the results of the study indicated that anterior medial movement was RMSD<0.75 in 2 cases, 0.75<RMSD<1.0 in 2 cases, RMSD=1.25 in 1 case, and RMSD=1.75 in 1 case. Also, anterior lateral movement was RMSD≤0.75 in 2 cases, RMSD=1.25 in 1 case, and RMSD=1.75 in 1 case. Moreover, posterior lateral movement was RMSD=1.5 in 2 cases Figure (9).

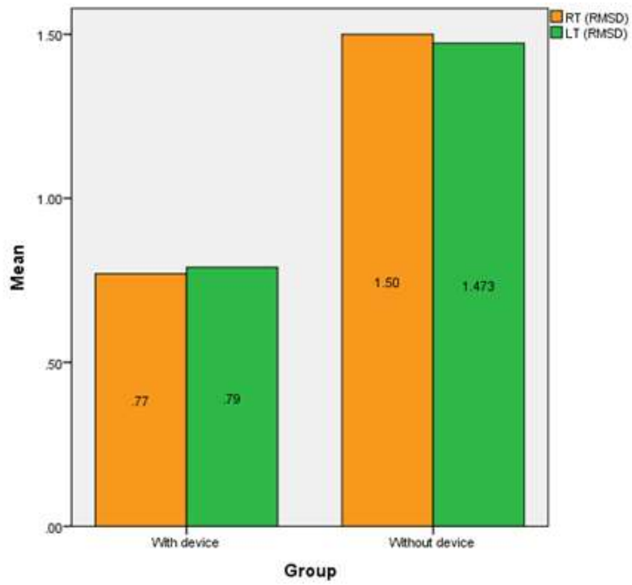

Figure (8): Amount of post-operative displacement of right and left condylar heads in group where the guide was used, and the group where device was not used

Discussion

For optimal condylar function, stability of the postoperative occlusion, and TMJ function, the optimum location of the condyles in the glenoid fossae is crucial. In the literature, a variety of methods have been suggested for achieving central occlusion and CR during plate fixation.

Orthognathic surgery complications like as condylar malposition might result in TMJ problems. According to Epker and Wyle [32], the proximal segment of mandible needed to be placed precisely during intraoperative fixation in order to reduce the likelihood of TMJ issues, provide stable surgical results, and prevent the possibility of condylar resorption [33]. In orthognathic surgery, the location of the proximal ramus and condyle can vary depending on various factors: Fixation system type, choosing an osteotomy plan for mandibular advancement or setback, the precision of the condylar CR location at fixation and the amount of extra bone between the proximal and distal bone segments at the osteotomy site.

The current method for condylar placement employs a bone-borne and bone-borne guide, and inter maxillary fixation with arch bars and wires to achieve occlusion. The virtual surgical planning (VSP) was translated to the operating room with full control of the proximal bone segments during fixation, to avoid condylar sag or condylar rotations. The repositioning surgical guides had two arms, one fixed on the anterior border of the ramus and the other fixed on fixed zygomatic bone that was not affected by surgical cuts.

The instrument's straightforward design enables the user to precisely align the mandibular segment with the condyles in CR by placing it in touch with the anterior margins of the ramus and zygomatic bone. The fragment is stabilized during fixation with a monocortical screw that is fastened to the ramus segment after passing through the guide. Traditional interocclusal splints, wax bite, and other methods can be used to

ORIGINAL RESEARCH
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determine the relationship between the upper and lower dental arches.

There are limited and conflicting studies comparing the use of condylar positioning devices (CPDs) with more established techniques [34, 35].

In a review done by Costa *et al*. [35] only 6 published in the English-language literature were found: three of them supported the use of CPDs, one supported the use of CPDs only in patients with temporomandibular disorders, and the others did not support the use of CPDs because they did not improve skeletal stability or TMJ function, irrespective of the skeletal deformities treated.

In our study condylar position in the glenoid fossae measured by two methods, the first is by utilizing the root mean square deviation (RMSD) and second is by comparing the post-operative condylar movement with pre-operative condylar position in medial, lateral, anterior, posterior direction inside the glenoid fossa. Results showed that using the guide decreased the amount of movement of condyles inside glenoid fossa as seen in results Table (1) the 6 cases with guide range of condylar head movement was (0.77-0.81), while range of movement of condylar head in group without device was (1.32-1.65) when measured by root mean square deviation RMSD.

The results of measuring by other method which was comparing the condylar head position in anterior, posterior, medial and lateral direction, showed that the amount of movement of condylar head was between(-1.49 _ -2.47) in anterior direction, while for patient without guide was between(+2.02 _ -4.72).

In posterior direction also the amount of movement was less in patients with guide (+1.54_ +2.09) when compared with patients without guide (+2.75_ -4.71), in medial direction the movement of condylar head was between (-1.24 _ -2.58) in patients using guide, while the movement of condylar was (+2.01_+5.00), again the movement of condylar head in patients with guide was less when compared with patients without guide, in lateral direction the same results was seen the patients with guide less movement was seen(+1.81_+2.96), while in patients without guide results was(-2.24_ -4.25).

The direction of the movement in patients with guide was in anterior-medial direction for two patients and anterior-lateral direction for one patient who had asymmetry, while direction of movement for patients without guide was in anterior-medial direction for one patient and anterior-lateral direction for second patient, while the patient with asymmetry the condylar movement was in posterior-lateral direction, this shows that direction of condylar head movement was more favorable in patients using guides which was in anterior-medial direction, even the case of asymmetry movement was in anterior-lateral direction which is more favorable than the case of asymmetry without guide which moved in posterior-lateral direction.

There are some limitation to this study due to limited number of cases available, limited number of published articles which made comparison with results from literature unavailable, cost of the guide, differences in anatomical landmarks can lead to poor adaptation of these guides, and more time in operating room.

Otherwise, this method confirms that an accurate and reproducible outcome can be obtained, minimum condylar head movement, desirable condylar head direction of movement was seen with centric occlusion and centric relation using CADCAM guides, if good pre operative preparation is available with good quality of Ct scans and design.

Conclusions

Within the limited number of cases of this study, the proposed guiding device design offered good clinical outcomes in terms of occlusion and optimal condylar repositioning as evaluated radiographically. The condylar linear movement was in anterior-medial direction which is more favourable than posterior lateral direction.

Recommendations

It would be useful to conduct a similar study with a bigger sample size, a longer follow-up period, and the use of more precise methods for assessing quality of life.

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Ethical clearance: Consents were taken from all patients prior to participation. The Kurdistan Board ethics committee approved the study before initiation.

Conflict of interest: Nil

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الدقة في إعادة تموضع الجزء القريب باستخدام دليل مخطط رقميًا مخصصًا في قطع العظم السهمي

بانو عادل مصطفى [١] ، سهى نافع الالوسي [٢]

الملخص

خلفية الدراسة: جراحة تقويم الفكين هي إجراء جراحي يستخدم على نطاق واسع .

اهداف الدراسة: لتصحيح المشاكل الوظيفية والجمالية. الإجراء الجراحي التقويمي الأكثر شيوعا هو قطع العظم السهمي الثنائي الذي يستخدم لإدارة زيادة أو نقص أو عدم تناسق الهيكل العظمي .

المرضى والطرائق: تم تضمين مجموعه (٦ مرضى) ١٢ لقمة في دراستنا جميعها مع سوء الإطباق ، والعضات المفتوحة وعدم التماثل ، من الجنسين الذكور والإناث ، وتتراوح أعمارهم بين ١٨ إلى ٤٠ عاما ، وجميع الحالات خضعت لفحوصات التصوير المقطعي المحوسب قبل الجراحة وبعدها.

النتائج: من خلال مقارنة الأشعة المقطعية قبل وبعد الجراحة فيما يتعلق بالمواقف اللقمية لكلا المجموعتين. كشفت النتائج أن هناك حركة أقل لرأس اللقمة في المجموعة مع الجهاز وكان اتجاه الحركة أكثر ملاءمة.

الاستنتاجات: أظهرت هذه الدراسة أن دليل مخطط رقميًا مخصصًا كان مفيدًا في إعادة وضع الأنماط بأقل قدر من الحركة بعد الجراحة واتجاه أكثر ملاءمة للحركة.

الكلمات المفتاحية: جراحة تقويم الفكين ، اللقمات ، أدلة CADCAM ، قطع العظم الانقسام السهمي ، الجزء القريب.

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