Original Article

Open reduction and internal fixation of zygomatic arch fracture by transbuccal instrumentation – A prospective clinical trial

ABSTRACT

Background and Purpose: The zygomatic arch is important to maintain facial projection as well as width. Hence, restitution of its form by open reduction and internal fixation (ORIF) is indicated following its fracture, in certain clinical scenarios. The contemporary surgical approaches are cutaneous with associated complications. This observational clinical trial was designed to evaluate intraoral reduction and transbuccal fixation of zygomatic arch fractures.

Materials and Method: Six patients requiring ORIF of the zygomatic arch were recruited for the study. The clinical parameters such as pain, swelling, mouth opening, facial nerve function, and scar were assessed in the pre-operative as well as post-operative period. Radiographic assessment of displacement and inter-fragmentary separation were studied on computed tomography (CT) images.

Results: Mean pre-operative mouth opening was increased from 28.33 ± 6.80 to 36.83 ± 1.94 (*P* value 0.03). Mean pre-operative swelling was decreased from 34.63 ± 5.41 to 29.71 ± 2.73 (*P* value 0.02). The pain decreased by day 7 in all the patients (*P* value 0.01). No facial nerve injury (*P* value 1) or scar formation (*P* value 0.002) was encountered in our study. The inter-fragmentary separation as assessed by CT analysis revealed satisfactory outcome.

Conclusion: Intraoral open reduction and transbuccal fixation is a simple, effective, and less invasive method to address zygomatic arch fractures with no complications.

Keywords: Fracture, ORIF, zygoma, zygomatic arch

INTRODUCTION

Isolated zygomatic arch fractures account for approximately 10% of all zygomatico-maxillary fractures and 14% of all facial fractures,[1] the incidence being attributed to its prominent position. The arch determines the transverse as well as antero-posterior dimensions of facial morphology, thus contributing to facial esthetics in a significant manner.[1] It also plays an important role in dissipating the masticatory load transmitted from the masseter muscle.[2] Reduction of these fractures is hence necessary to maintain both functional and cosmetic outcomes.

Mostly these fractures are managed by a closed method comprising of "Reduction alone" without any subsequent fixation.[3] They have been proved to be adequate as

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the periosteum as well as the temporal fascia hold the fractured fragments together.[4] Reduction of the fractures may be performed by extra-oral or intraoral techniques.[5] However, closed management presents many difficulties; (1) inability to visualize/access the exact location and type of fracture, (2) lack of fracture exposure to intraoperatively confirm the reduction outcomes,[6] especially in the absence of radiographic imaging, and (3) impossibility of fracture fixation when indicated.[7] Open reduction and internal fixation (ORIF) is mandatory in many clinical scenarios to re-establish the sagittal buttress. The definite indications for open reduction and fixation include laterally and inferiorly displaced fractures, fractures that are unstable after closed reduction, and comminuted and malunited arch fractures.[8] The commonly used approach to access the zygomatic arch for ORIF is through extra-oral incisions, namely, coronal and pre-auricular incisions. Often these incisions are associated with complications.[9] Many modifications in surgical procedures have been proposed to minimize complications.[10] But even these have been associated with limitations in terms of time, expertise, and cost involved.[11]

This prospective study was therefore designed to assess the efficacy of a less invasive surgical technique to reduce and fix the zygomatic arch with minimal surgical morbidity.

MATERIALS AND METHODS

Study design

The study was designed as an observational clinical trial. Ethical Clearance was obtained from SRMDC Institutional Ethical Committee with Ref no. SRMDC/IRB/2018/MDS/No.404 and date of approval - 31/08/2018. The study was conducted according to STROBE guidelines.

Patient selection

The study sample included patients who reported with zygomatic arch fractures. All the patients were provided with a detailed explanation of the study and written consent was obtained for the clinical trial.

Inclusion and exclusion criteria

The inclusion criteria designated were American Society of Anesthesiologists.

(ASA)-I patients requiring ORIF of zygomatic arch and patients aged between 18 and 50 years. A diagnosis of zygomatic arch fracture was made in the presence of the following computed tomography (CT) characteristics; (1) Any disruption in the continuity of the zygomatic arch extending from the jugal point to the root of the arch on the temporal bone, (2) Disarticulation at the ZT suture, and (3) Fracture at the root (posterior end) of the zygomatic arch with separation from the temporal bone. Patients requiring closed reduction of the zygomatic arch and medically compromised were excluded from the study.

Parameters and assessment scales

Clinical parameters

All patients were thoroughly evaluated for signs and symptoms related to zygomatic arch fracture, specifically pain, mouth opening, and swelling objectively by Investigator 1. The various clinical parameters assessed were pain, swelling, mouth opening, and motor function of the facial nerve. These were assessed in the pre-operative as well as post-operative period. Pain was assessed by using a Visual Analog Scale.[12] Maximal mouth opening was measured as the inter-incisal distance in millimeters by using a scale. The grade of swelling was assessed by using fixed reference points as suggested by Gogulanathan *et al*.,[13] using a scale. Facial nerve function was assessed by using the House-Brackmann grading system.[14] All the five terminal branches of the facial nerve were assessed for function and recorded. The surgical scar on the face was analyzed in the post-operative period using the Vancouver Scar Scale.[15]

Radiographic parameters

The fracture was assessed using CT (axial, sagittal and coronal) in the pre-operative and post-operative period. This was performed by investigator 1 in the pre-operative period. Two parameters, namely, displacement and inter-fragmentary separation were assessed. The displacement of fracture was analyzed in the antero-posterior, transverse, and supero-inferior planes. Antero-posterior displacement of the fractured arch was calculated as the difference between reference lines AB and AB' on the axial section [Figure 1].[16] Transverse displacement of the fractured arch was calculated as the difference between the reference lines CD and CD' on axial section [Figure 1].[17] Supero-inferior displacement of the fractured arch was calculated as the angle (Z) between the reference lines X and Y on 3D CT [Figure 2]. Inter-fragmentary separation on the fractured arch was assessed as the presence or absence of separation between two fracture fragments on a 3D CT section.

Intraoperative procedure

A standardized surgical procedure was followed by a single operating surgeon (Investigator 2- author 3) for all patients. Under general anesthesia, ORIF of the zygomatic arch was done using a transoral approach. The surgical procedure was standardized as follows:

Under general anesthesia with nasal intubation, the vestibular incision was placed in the maxillary vestibule extending from

the canine to the first molar on the side of the fracture. Sub-periosteal dissection was done to expose the lateral aspect of the zygomatic arch. Transoral reduction of the arch fracture was done using a zygomatic and Molt's periosteal elevator. Using a no-11 BP blade, a stab incision was placed in the cheek corresponding to the zygomatic arch. Adequate care was taken to avoid injury to the facial nerve. Trocar was inserted through this incision for introducing the cannula and for instrumentation [Figure 3]. For fractures involving the posterior arch, a mini pre-auricular incision was also made to access the root of the arch [Figure 4]. A titanium mini-plate (ORTHOMAX, INDIA 2 mm system) was used to fix the fractures. The length of the plate was chosen according to the fracture pattern. The plate was contoured pre-operatively, using a standard tessellation language (STL) model of the patient. Fracture fixation was done using 6-mm screws. A periosteal elevator introduced under the medial surface of the arch stabilized the fracture fragments and facilitated screw tightening. 3-0 vicryl was used for the closure of the intraoral incision and a single suture was used to approximate the stab incision with 5-0 prolene. Figures 5-7 (Supplemental data) are the pre-operative and post-operative CT images of the patient shown in Figure 3.

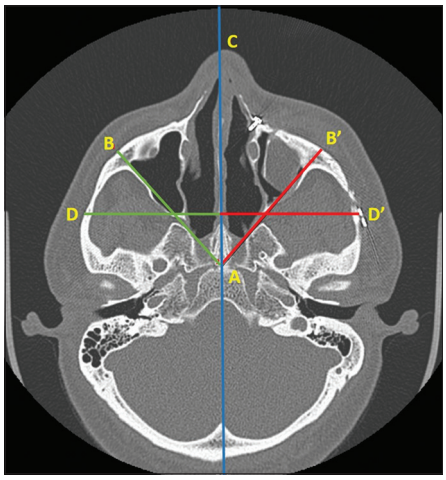

Figure 1: Demonstrates the assessment of arch symmetry. The green and red lines denote the fractured and the non-fractured sides, respectively. Line AB extends from point A to point B, and line AB' extends from point A to point B'. Line CD extends from point C to point D, and line CD' extends from point C to point D'. Point A - center of spheno-occipital joint in the base of the skull, Point B - malar prominence on the non-fractured side, Point B' - malar prominence on the fractured side. Point C – point on the line drawn along the septal bone, point D - lateral most point on the zygomatic arch on the non-fractured side, and point D'- lateral most point on the zygomatic arch on the fractured side

Review protocol

Parameters such as pain, maximal mouth opening, and swelling were recorded in the pre-operative period as well as on the 1st, 3rd, and 7th post-operative days by investigator 3. Motor function of the facial nerve was evaluated pre-operatively and on days 1, 7, and 28 post-operatively. The scar was assessed

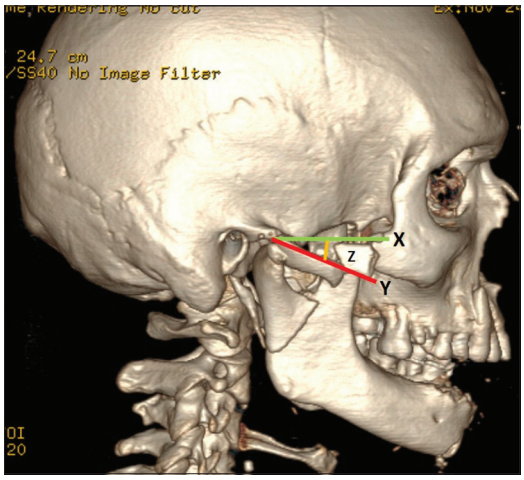

Figure 2: Demonstrates the displacement in supero-inferior direction. Line X is an imaginary line connecting the non-fractured ends of the zygomatic arch, line Y is the superior border on the fractured zygomatic arch, and point Z is the angle formed by line X and line Y

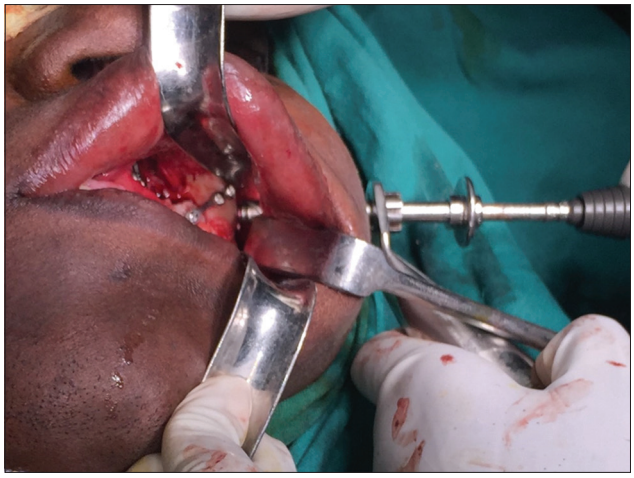

Figure 3: Demonstrates transbuccal instrumentation

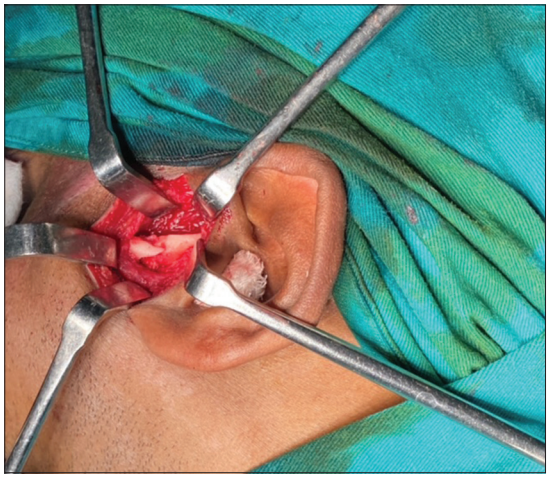

Figure 4: Demonstrates mini pre-auricular incision for fractures involving the posterior arch

on days 1, 7, and 28 post-operatively. CT assessment was done pre-operatively and in 4th week post-operatively.

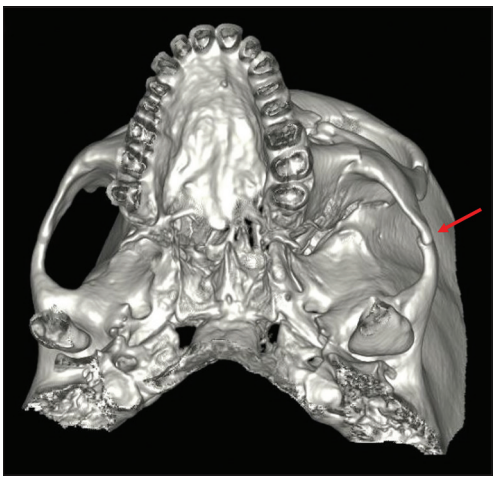

Figure 5: Demonstrates the pre-operative 3D CT image of the displaced zygomatic arch fracture

Figure 6: Demonstrates the post-operative 3D CT image of zygomatic arch fixation by transbuccal instrumentation

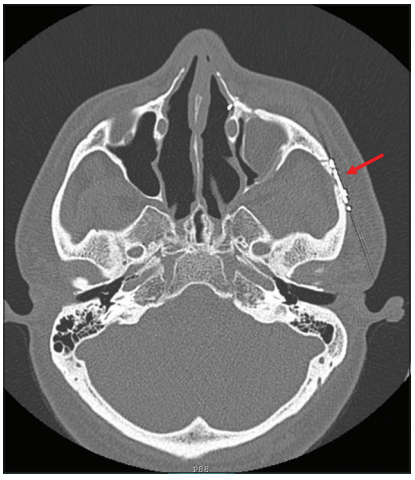

Figure 7: Demonstrates the post-operative CT axial section of zygomatic arch fixation by transbuccal instrumentation

Statistical tests

Descriptive statistics for pain, mouth opening, swelling, facial nerve function, scar assessment [Table 1], and radiographic assessment were recorded [Table 2]. The normality of data was assessed using Kolmogorov-Smirnov and Shapiro-Wilks normality tests. Pain score and mouth opening followed normal distribution of data while swelling, facial nerve assessment, and scar score did not follow normal distribution. Both parametric and non-parametric tests were done for statistical analysis [Table 3]. Statistical analysis was done using IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. (Armonk, NY: IBM Corp.). The significance level was fixed as 5% ($\alpha = 0.05$).

RESULTS

Clinical study

The mean mouth opening increased in all six patients from pre-operative 28.33 mm to 36.83 mm on post-operative day 7 which was found to be statistically significant (*P* value - 0.03). The mean extra-oral swelling decreased in all six patients from pre-operative 34.63 mm to 29.71 mm on post-operative day 7 which was found to be statistically significant (*P* value - 0.02). The nerve examination was found to be normal in all six patients pre-operatively and on the post-operative days 1, 7, and 28 which was statistically insignificant (*P* value – 1). The scar reduced in size from post-operative day 1 and became imperceptible by post-operative 4th week in all six patients and was found to be statistically significant (*P* value – 0.002). The pain decreased by the end of post-operative day 3 in all six patients which was found to be statistically significant (*P* value – 0.0152).

Radiographic study

The mean displacement in the antero-posterior direction increased from pre-operative 68.50 to post-operative 70.76 (*P* value – 0.95). The mean displacement in the transverse direction decreased from pre-operatively 63.56 to post-operative 62.28 (*P* value – 0.96). The mean displacement in the supero-inferior direction decreased from pre-operative 21.66° to post-operative 1.50° which was found to be statistically significant (*P* value – 0.043). Radiographic results of inter-fragmentary separation demonstrated good reduction with nil separation post-operatively (*P* value – 0.0022).

DISCUSSION

The surgical management of arch fracture plays a key role in restoring facial anatomy, function, and esthetics.[5] The arch fracture can be managed either by closed reduction or ORIF based on the clinical presentation[4]; while a majority

Table 1: Pre-operative and postoperative measurements of all clinical parameters

Cases	Mouth opening (mm)				Pain score (vas)*				Swelling (mm)				Facial nerve examination				Scar score (vss)**		
	Pre-op	Day 1	Day 3	Day 7	Pre-op	Day 1	Day 3	Day 7	Pre-op	Day 1	Day 3	Day 7	Pre-op	Day 1	Day 7	Week 4	Day 1	Day 7	Week 4
1.	22	27	31	36	7	3	0	0	38	33.8	31.5	30	I	I	I	I	2	1	0
2.	25	30	33	37	8	2	0	0	39	35.5	32	30.5	I	I	I	I	2	1	0
3.	20	26	30	38	6	2	0	0	33	32.5	34.8	32	I	I	I	I	2	1	0
4.	35	30	27	35	0	1	0	0	32	34.5	33	31	I	I	I	I	2	1	0
5.	35	28	33	40	2	1	0	0	25.8	28.6	26.6	24.3	I	I	I	I	2	1	0
6.	33	25	30	35	9	2	0	0	40	36.5	33	30.5	I	I	I	I	2	1	0

*Visual analogue scale, **Vancouver scar scale

Table 2: Radiographic measurements of displacement in anteroposterior, transverse and supero-inferior direction

Cases	Anteroposterior			Transverse width			Supero-inferior displacement	
	Non-fractured (mm)	Fractured (mm)		Non- fractured (mm)	Fractured (mm)		Fractured (degrees)	
		Pre-op	Post-op		Pre-op	Post-op	Pre-op	Post-op
1	67.4	61.3	67.5	60.6	67.3	60.9	23°	3°
2	66.4	70.4	66.7	60.6	55.6	60.7	10°	1°
3	71	74	71.3	66.5	69.1	66.1	40°	3°
4	74.7	69.9	73.2	65.3	59	65.1	0°	0°
5	69.4	64.3	69.5	61.6	66.2	61.9	34°	2°
6	76.5	71.1	76.4	58.7	64.2	59	23°	0°

Table 3: Statistical analysis

Parameters	Statistical test	*P*	Significance ($P<0.05$)
Mouth Opening	Paired *t*-test	0.034	Significant
Swelling	Wilcoxon Signed-Ranks Test	0.027	Significant
Facial Nerve Examination	Fisher's exact test	1	Not significant
Scar Score		0.0022	Significant
Pain		0.0152	Significant
Superioinferior Displacement	Wilcoxon Signed-Ranks Test	0.043	Significant
Anteroposterior Displacement	*t*-test	0.95	Not significant
Transverse displacement		0.96	Not significant

of arch fractures are effectively managed by the closed method, the open method is indicated due to limitations associated with the closed method and in specific, fracture patterns which cannot be effectively addressed by the closed method. Contemporary surgical approaches for ORIF include cutaneous incisions such as coronal, pre-auricular, Dingman's suprazygomatic incision, suprazygomatic arch incision, and existing lacerations.[18] These conventional approaches present with several disadvantages like scarring, temporal hollowing, scalp numbness, alopecia, increased blood loss, transient facial paresis, facial nerve injury, inadequate access to the anterior third of the arch, keloid formation, and meatal stenosis.[5]

Panneerselvam *et al*. demonstrated the efficacy of transbuccal fixation of zygomatic arch fractures.[19] This study was designed to assess the efficacy of the earlier-mentioned technique in the reduction and fixation of the zygomatic arch, the surgical morbidity, and the precision of the technique.

The objectives of surgical management of zygomatic arch fractures involve establishing adequate visualization of the fracture site, access, and ease of instrumentation with minimal surgical morbidity. In our study, the vestibular incision ensured adequate access to the inferior and lateral surface of the zygomatic arch with considerable ease. The technique required minimal stripping of the masseter muscle fibers [Figure 8]. The concerns regarding any compromise in the action of masseter muscle were negated by the demonstration of adequate bite force and mouth opening in our patients in the post-operative phase.[20] The relative decrease in mouth opening on the 1st post-operative day may be attributed to the surgical insult/edema which was eventually restored by post-operative day 7. Superior post-operative outcomes were observed in relation to other parameters which indicated the clinical efficacy of the technique.

To avoid facial nerve damage during trocar placement, a stab incision was placed at a safe anatomical zone described

by Dahlke and Murray.[21] The temporal branch of the facial nerve lies in the danger zone, which is bounded by two imaginary lines; the inferior line extending from the lateral eyebrow to the earlobe and the superior line connecting the tragus to the upper forehead crease. Introducing the trocar just below this zone ensured safe transbuccal instrumentation. The other anatomical structure at risk of injury is the parotid duct. Caution was exercised to avoid injury to the duct.[22] Our study also used CT imaging to assess the surgical outcome in all three planes. Comparison of the non-fractured arch with the post-operative fractured arch revealed successful restoration of arch dimensions. However, the statistical outcome was found to be insignificant due to the smaller sample size. Precision in the accuracy of plate fixation may be improved by pre-operative planning using STL models.[23]

Our technique vs other minimally invasive techniques

Many invasive techniques have been proposed to reduce the incidence of post-operative complications or morbidity. Czerwinski and Lee were the first to perform ORIF of arch fractures under direct, magnified visualization by endoscopic approach through small, well-hidden incisions.[24] Chen *et al*.[9] had conducted a study involving 15 patients who underwent fixation of the zygomatic arch through an endoscopic approach and reported 13% frontal branch weakness. Lee *et al*.[25,26] reported a clinical case series and a cadaveric evaluation of the endoscopic approach and reported 7% of the frontal branch of facial nerve weakness. Xie *et al*.[27] reported a case series of seven patients where he performed ORIF of isolated zygomatic arch fracture with an endoscope through a small pre-auricular incision. However, the limitations reported with this technique involved adequate training in the manipulation of the endoscope, blood contamination on the tip of the endoscope, and complex armamentarium. Oscar Badillo *et al*.[28] endoscopically approached the arch along with a "z instrument" and reported fixation with good visibility and negligible nerve damage. But this procedure required three additional cutaneous incisions as well as a special armamentarium. With our technique, transbuccal instrumentation could be done with minimal instruments and with only a stab incision.

Merits and demerits

The technique proposed by us presents numerous advantages; (1) negates cutaneous incision and hence no scar is perceived in the post-operative period [Figure 9], (2) easy and quick to perform the technique, (3) reduces blood loss, (4) avoids injury to the facial nerve, and (5) permits precise angulation of the screw. However, this technique has its own limitations. Fractures involving the posterior third of the arch required an additional pre-auricular incision [Figure 10]. But this is comparatively less morbid than a coronal or regular pre-auricular with temporal extension for managing arch fractures. Further, a fractured

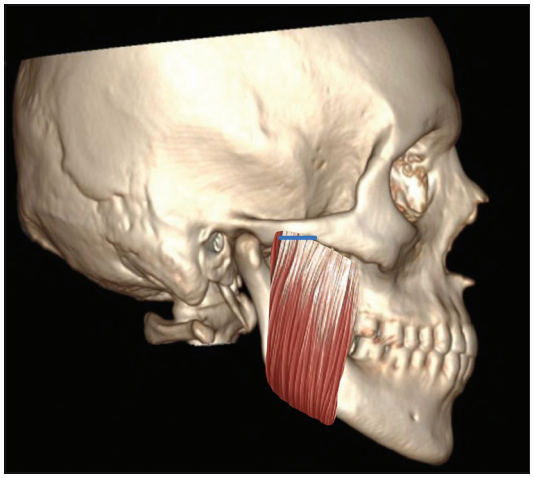

Figure 8: Demonstrates minimal stripping of the masseter muscle

Figure 9: Demonstrates post-operative image of the stab incision

Figure 10: Demonstrates the pre-auricular incision used for the posterior third of the zygomatic arch

arch malunited by a fibrous union may be managed by our intraoral transbuccal method. However, a bony malunion would require the conventional approaches. The outcome of the study may be improved and more clinical relevance may be derived by conducting a randomized control trial with a larger sample size.

CONCLUSION

The intraoral reduction and transbuccal fixation of the zygomatic arch is an efficient method of restoring the dimensions of a fractured zygomatic arch. It is simple in technique, less invasive, provides adequate access to the zygomatic arch, preserves the integrity of the facial nerve, and ensures negligible surgical morbidity. The technique also ensures favorable cosmetic outcomes by leaving an imperceptible scar.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the journal. The patient understands that his name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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