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Surgical management of intra-articular impression distal radius fracture

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Purpose Improve results of surgical management of intra-articular impression distal radius fractures (DRF). **Material and methods** Retrospective study of 69 patients with intra-articular impression DRF surgically treated between 2011 and 2015 was performed. Inclusion criteria were impression intra-articular epimetaphyseal or metadiaphyseal defects seen on CT scan, open reduction and plating, and follow-up period of at least 36 months. Two groups of patients were identified to compare the effectiveness of new surgical technologies and bone grafting of impression defect applied in index group (n = 35) and conventional surgical technology with no graft in the control group (n = 34). Radiological, clinical and statistical methods of study were used. Parametric and non-parametric statistical tests were employed to evaluate significant differences. The difference between radial inclination (RI) and palmar tilt (PT) was measured to assess reduction persisted. DASH questionnaire (1996) was an outcome measure used for functional assessment. **Results** Intra-articular impression DRF were mostly seen in older adults and females with mean age of 48.9 ± 16.3 years. There were 14 (20.3 %) male and 55 (79.7 %) female patients. D.L. Fernandez type II fracture was most common (43.5 %). RI radiometric parameters measured 13.34 ± 0.43 ° in index group and 9.33° ± 0.51° (p = 0.003) in the control group at 3-month follow-up. RI was noted to decrease in the control group and showed maximum values of 3.71° ± 0.31°, p < 0.05 at 3-month follow-up. Excellent and good results were observed in index group at 36-month follow-up measuring DASH score of 94.2 % vs. 61.8 %, p < 0.05. **Conclusion** Surgical repair of intra-articular impression DRF combined with new approach and modern bone grafting materials facilitated restoration of optimal radiometric parameters of the distal radius with bone graft preventing secondary impression and providing reliable bone fixation with the possibility of early rehabilitation.

Keywords: radius, intra-articular fracture, impression fracture, bone graft, surgical treatment

INTRODUCTION

Intra-articular distal radius fracture (DRF), a common fracture, accounts for 33 % of all skeletal injuries with poor outcomes reported in 37.9 % of the cases. DRF usually occur in active elderly individuals and young adults with high energy injury [1, 2]. There is a close correlation between anatomical realignment of articular surfaces maintaining proper geometry of intra-articular component of the radius and functional result in patients with intra-articular DRF. Conservative treatment of impression intra-articular DRF using plaster cast is reported to result in secondary displacement in 16.5 to 88.3 % of the cases and neurodystrophic regulation disorder in 25.0 % and surgery is now favoured [3, 4]. Surgical treatment of DRF is common and includes (1) closed reduction and pinning; (2) transosseous osteosynthesis with external fixation devices; (3) open reduction and plating, and (4) combined methods. Inaccurate reduction of articular radial surface, inadequate surgical access and metal fixator, refusal from osteoplasty of impression defect result in severe posttraumatic osteoarthritis, deformity and joint contractures in 5.8 to 28.0 % of the cases [5, 6].

Closed reduction and pinning is normally applied for stable extra-articular fractures with the limitation of comminution. Many authors report a high complication rate after pinning due to unstable fixation associated with secondary bone displacement and pin migration, and inadequately placed pins with resultant impaired tendons, nerves and pin tract infections. Pinning normally requires additional external immobilisation that is claimed to be a precipitating factor of neurodystrophic regulation disorder [7, 8].

Transosseous osteosynthesis as treatment option for DRFs is primarily reserved for comminuted intra-articular fractures. Although external fixation found its place as an established method the practice is associated with some disadvantages. T. Gausepohletal et al. concluded that external fixation of comminuted fractures with impaction failed to provide stable fixation and prevent secondary impression of articular radius surface with loss of radial inclination and volar tilt. Moderate collapse of impression site was observed in more than 50 % of the cases [9]. Complications associated with overdistraction include

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neurodystrophic regulation disorder with characteristic stiff fingers, pain and impaired fracture consolidation. It should be noted that external fixation is essential for open and complicated fractures [10, 11].

Advantages of plating comprise accurate anatomic reduction and stable fixation with the possibility of early motion in radiocarpal and radioulnar joints. In recent years, more surgeons opt for a volar fixed-angle plate allowing a permanent maintenance of reduction even in polyfocal impression intra-articular injury. The volar approach is indicated for DRFs in individuals with evident osteoporosis. The angularly stable plate attached to the bone with locking bone screws and lockable holes enables the effective use in DRF [12, 13].

With the advent of emerging technologies controversy remains regarding operative treatment of impression intra-articular DRFs. The existing surgical approaches to DRFs provide poor visualisation of the fracture site that makes reduction of articular surface and bone fixation difficult. Questions of plasty of impression intra-articular defects and the choice of osteoplastic material are still open.

The aim of the study was to improve results of surgical management of impression intra-articular distal radius fractures.

MATERIAL AND METHODS

Retrospective cohort study included short- and long-term results of 69 patients with impression intra-articular DRFs surgically treated at trauma department № 1 of the Central Municipal Clinical Hospital (CMCH) № 24 between 2011 and 2015. Design and protocol of the study was approved by the institutional review board of the Ural State Medical University (USMU). There were two inclusion criteria: 1) impression intra-articular defect in either epimetaepiphysis or metadiaphysis verified by computed tomography; 2) open reduction and plating. Extra-articular DRF and open injuries were excluded from the study. Mean patients' age was 48.9 ± 16.3 years (range 18 to 74 years; 16.3 is mean deviation σ). There were 14 (20.3 %) males and 55 (79.7 %) females. DRF were mostly seen in patients (43.5 %, $p < 0.05$) aged between 50 to 74 years with age related involuntive osteoporosis. DRFs resulted from a fall on an outstretched hand from standing height (hypoergic trauma) in 51 (73.9 %) patients, RTA in 5 (7.2 %), a fall from a height of more than 1.5 m in 2 (2.9 %) cases. Sport related injury was documented in 9 (13.1 %) patients during skiing and (2.9 %) cases during skating. The majority of the patients (n = 47; 69.7 %) were referred from emergency ward; 13 (18.8 %) were delivered to admission department by ambulance crew; 6 (8.7 %) patients sought medical assistance by themselves and 2 (2.8 %) were referred from regional hospitals of Sverdlovskaya oblast.

Patients enrolled in the study (n = 69; 100.0 %) were subdivided into index and control groups depending on the technology of surgical treatment performed. Index group (n = 35; 50.7 %) comprised the patients who underwent surgical treatment using new technologies developed during thesis research. Control group (n = 34; 49.3 %) was consisted of the patients treated with conventional surgical methods of intra-articular skeletal injury. Indications for surgical treatment in both groups included unstable impression intra-articular injury, incongruence in radiocarpal joint and the possibility of early functional rehabilitation of injured joint. Osteosynthesis was produced 5 to 8 days of injury with no statistically significant differences in bed/day in both groups, $p > 0.05$. Volar fixed-angle plates ("Osteosynthesis", Rybinsk and DC plate for DRF) were used in both groups. Classical principles of operative treatment of intra-articular fractures were employed [12, 13]. Surgery was performed with pneumatic tourniquet. Dressings were regularly changed after surgery until the wound healed. Exercise therapy was administered under supervision of physiotherapist and magnetic therapy recommended to reduce swelling. Postoperative immobilisation was not used.

Injuries were grouped using classification offered by D.L. Fernandez, 1987 [14]. Clinical and statistical characteristics of index and control groups are presented in Table 1.

Table 1

Clinical and statistical characteristics of index and control groups of patients with intra-articular DRF fractures classified according to D.L. Fernandez

Group	Mean age, years	♂ (N/%)	♀ (N/%)	type II	type III	type IV	type V	Total (N/%)
Index	53.4 ± 11.7	7/20.0	28/ 80.0	12 / 34.3	16 / 45.7	5 / 14.3	2 / 5.7	35 / 100.0
Control	40.2 ± 17.9	7/20.6	27/ 79.4	14 / 41.2	13 / 38.2	2 / 5.9	5 / 14.7	34 / 100.0

* Study groups by gender, age and fracture pattern were identified as representative ($p < 0.05$ by Shapiro-Wilk test).

Patients of the control group (n = 34; 49.3 %) were treated according to classical principles of surgical management of radius injuries established at the hospital. Closed manual reduction of the fracture and cast immobilisation was produced at the admission department at the first stage. With failed closed manual reduction and persisted incongruence in radiocarpal joint open reductions and plating was performed at a surgical department as the second phase of treatment. No grafting of impression defects was produced. A modification of anterior Henry's approach [15] was employed exposing the pronator quadratus muscle during dissection of deep layers.

Two-staged surgical procedure was performed for index group. Primary reduction was produced with circular distraction module of external fixation device applied to forearm and hand to allow short-term realignment in radiocarpal joint. Open reduction, plating and grafting of impression defect ensured final fracture stabilisation at the second phase. New technological approaches devised at the hospital were recruited for index group.

Technique of open reduction of osteosynthesis of DRFs (patent RF № 2601850) was devised during thesis research and implemented into clinical practice to repair injuries of all patients (n = 34; 100.0 %). The method facilitated biomechanically reliable reduction of intra-articular comminuted fracture providing conditions for regaining pain free motion in the radiocarpal joint at a short term. Distraction module of the Ilizarov frame was applied to fix the forearm and hand in a position assigned with distal wire oriented from the proximal portion of IInd metacarpal bone to the distal portion of the Vth metatarsal providing ulnar deviation and radial inclination of the distal radius. Ligamentotaxis was ensured by distraction between the rings using image intensifier facilitating bone reduction. The reduced fracture was plated, distraction external fixation module removed, final radiography performed and the wound sutured by layers [16]. T-shaped chisel (patent RF № 160622) was devised and introduced into practice to harvest bone tissue and approved by local ethical board of the Ekaterinburg CMCH № 24 [17]. The chisel was designed to provide less invasive harvesting of corticocancellous autologous graft, prevent donor site complications and reduce surgical time. The device was used in 8 (22.9 %) cases. L-shaped anterolateral access to the distal radius (patent RF № 2625647) [18] was devised and successfully introduced into practice for greater exposure of the wound in comminuted fractures of the medial part of the distal radius avoiding incision distally to articular line to prevent painful scars and limited flexion/extension of the wrist at early postoperative period.

Bone substitutes used included autologous graft harvested from iliac crest (n = 8; 22.9 %), synthetic beta-tricalcium phosphate (Science & BioMaterials, France) (n = 16; 45.7 %), xenoplastic grafts (Connectbiopharm, Russia) (n = 9; 25.7 %) and carbon fibrous nanostructured implant (Nanotechmedplus, Russia) (n = 2; 5.7 %).

Clinical, radiological, radiographical, computerised tomographical and statistical methods were employed in the study. Outcomes of surgical treatment were evaluated with DASH score, 1996 [19]. Images were digitised and processed with WeasisMedicalViewer software version 2.17.1 to determine reference roentgenometric parameters. Roentgenometric evaluation of reduction included radial inclination angle and palmar tilt on lateral view using the technique offered (patent RF № 2626375) [20]. Statistical analysis was used to determine differences between the groups by parametric procedures with data being approximately normally distributed and non-parametric Mann-Whitney, Chi-square, Shapiro-Wilk tests for independent and conjugate distributions. The Pearson correlation coefficient measured linear correlation between the variables. $P < 0.05$ was considered statistically significant. Statistical data analysis was performed using Stata software (version MP 13.0 SN 3471502014).

RESULTS

Homogeneity of the groups was assessed by gender, age and fracture pattern for statistical confidence. Groups were evaluated in pairs using nonparametric procedure and conjugate Chi-square criteria for quality attributes (gender and AO/ASIF fracture type) with the significance threshold set at $p < 0.05$. $P < 0.05$ determined for targeted parameters allowed us to reject hypothesis of correlations and consider groups being statistically homogeneous.

The technique developed at the hospital was used for roentgenometric evaluation of bone reduction. The difference between radial inclination angle

(RIA) and palmar tilt angle (PTA) was calculated postoperatively and at follow-up terms using WeasisMedicalViewer software (version 2.17.1). Mathematical expression used to calculate absolute values were as follows: (1) $\Delta\eta = |\eta n - \eta 0|$ and (2) $\Delta\phi = |\phi n - \phi 0|$, where η was a radial inclination angle and ϕ was a palmar tilt angle. RIA was measured as an angle between one line connecting the radial styloid tip and the ulnar aspect of the distal radius and a second line perpendicular to the longitudinal axis of the radius on anteroposterior view. The normal radial inclination averages 23° and has a range of 13°-30° [15]. Palmar tilt was measured on a lateral radiograph and represented the angle between a line along the distal radial articular surface and the line perpendicular to the longitudinal axis of the radius at the joint margin. The normal volar tilt averages 11° and has a range of 5°–16° [15]. Measurements of reference angles at 3, 6 and 18 months after surgery are presented in Table 2.

As seen in Table 2, patients of index group showed ΔRIA measuring from 0° to 2° 3.7 times more at 3-month follow-up as compared to the controls whereas controls' ΔRIA measured more than 4° 2.8 times at 18 months after surgery. ΔPTA appeared to be less sensitive and showed no statistically significant differences in both groups. Maximal loss of reduction in radial inclination was observed in controls 3 months after surgery. Mean postoperative RIA measured 15.71 ± 0.54 [95 % CI 15.17–16.25] for index group and 14.74 ± 0.71 [95 % CI 14.03–15.45] for controls with no significant difference in RIA found in both groups and Mann-Whitney U test measuring 504.0 at $p = 0.203$). On the other hand, mean RIA measured 13.34 ± 0.43 [95 % CI 12.92–13.78] in index group and 9.33 ± 0.51 [95 % CI 8.82–9.84] for controls at 3 months after surgery with statistically significant differences and Mann-Whitney U test measuring 41.0 at $p = 0.003$). Statistically significant decrease in RIA (ΔRIA = 3.71 ± 0.31) was noted in control group at 3 months after surgery whereas no significant differences in RIA and PTA were observed in both groups at other terms. Decreased RIA in patients of control group at 3 months after surgery can be attributed to secondary impression/collapse of the distal radial articular surface in absence of bone substitution of impression defect.

The DASH outcome measure was developed by the American Academy of Orthopaedic Surgeons in 1996 [19]. It is a 30-item, self-report questionnaire that contains 6 modules intended to assess the upper extremity disability and symptoms. DASH scores of index and control groups calculated at 3, 12 and 36 months after surgery are presented in Table 3.

Table 2

Differences in radial inclination (ΔRIA) and palmar tilt (ΔPTA) (%) in patients of index and control groups at 3, 6 and 18 months after surgery (x – targeted difference, degrees)

Description	Term, months	Group of patients					
		index, n = 35, 100 %			control, n = 34, 100 %		
		$0 \le x < 2$	$2 \le x \le 4$	$x > 4$	$0 \le x < 2$	$2 \le x \le 4$	$x > 4$
ΔRIA	3	54.3	45.7	0.0	14.7	82.4	2.9
	6	8.6	77.1	14.3	0.0	61.8	29.4
	18	8.6	71.4	20	0.0	44.1	55.9
ΔPTA	3	82.9	17.1	0.0	67.6	26.5	5.9
	6	48.6	45.7	5.7	67.6	26.5	5.9
	18	5.7	77.1	17.1	67.6	26.5	5.9

Table 3

Outcomes of surgical treatment of index and control groups evaluated by DASH score (1996) at 3, 12 and 36 months after surgery

Term, months	Group of patients							
	index, N = 35, 100 %				control, N = 34, 100 %			
	excellent	good	fair	poor	excellent	good	fair	poor
3	74.3	20	5.7	0	50	32.4	17.6	0
12	65.7	34.3	0	0	47.1	20.6	26.5	5.9
36	57.1	37.1	5.7	0	47.1	14.7	29.4	8.8

As seen in Table 3, excellent and good outcomes were observed in 94.2 % of patients of index group at 36 months after surgery with 5.7 % of fair and none of the poor results. Controls showed 61.8 % of excellent and good results, 29.4 % fair and 8.8 % poor outcomes (pain, wrist contracture due to posttraumatic arthritis of radiocarpal joint).

Clinically important postoperative complications developed in 9 (13.0 %) cases in both groups. Secondary radial displacement of more than 5 mm was observed in 5 (7.3 %) controls that caused incongruence in radiocarpal joint and early signs of arthritis (secondary impression resulted from complicated hyperergic fracture and absence of bone substitution for impression fragment). Two (2.9 %) patients of index group developed infection and inflammation at early postoperative period that was resolved with secondary surgical treatment of the wound and removal of the plate replaced with Ilizarov external fixation in the case of carbon fibre nanostructured implantation. Percutaneous tear of the long digital flexor tendon occurred in one (1.4 %) patient of index group at 6 months and was surgically repaired. One (1.4 %) patient of control group experienced broken metal fixator at 3 months that was surgically treated with hardware removal, reosteosynthesis and bone autologous graft harvested from iliac crest.

Clinical instance. A 54-year-old female patient К. presented with DRF that was fixed with distraction module of external fixation device for primary stabilisation and realignment in radiocarpal joint at the operating room of admission department. Surgery was produced via L-shaped anterolateral approach offered after 6 days with swelling resolved. Bone reduction was achieved, bone defect filled with xenoplastic graft and fracture fixed with LCP plate. Anatomy of the radiocarpal joint and congruence of the articular surfaces were restored with free motion in the joint ensured and minimal discomfort experienced during rehabilitation. Stages of surgical treatment of the patient are presented in Figure 1.

Radiological evaluation showed anatomy of radiocarpal joint and congruence of articular surfaces restored. Full range of passive motion was achieved intraoperatively. Mobilisation of radiocarpal joint started next day after surgery with passive and active exercises. The fracture united 7 weeks after surgery. Range of motion in the radiocarpal joint restored after 6 weeks. Function of the radiocarpal joint at 3 months after surgery is shown in Figure 2.

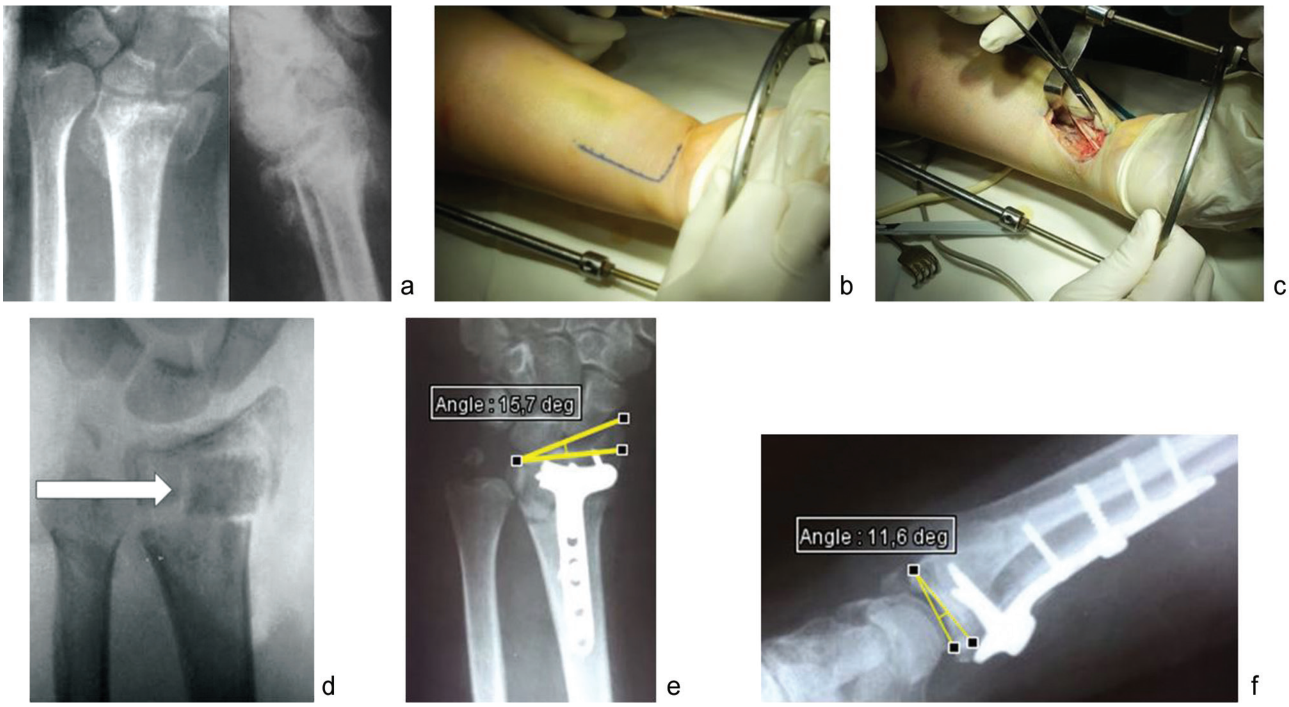

Fig. 1 Radiographs and stages of surgical treatment of a 54-year-old female patient K. (intraoperative photographs) showing (a) anteroposterior and lateral views of DRF AO/ASIF type C2.1 and D.L. Fernandez type III, RIA of 3.7° and RTA of 20.4°; (b) L-shaped approach with blue marker; (c) a stage of DRF reduction; (d) image intensifier of DRF after substitution of the defect with xenoplastic graft (an arrow); (e) anteroposterior view of DRF demonstrating congruence of radiocarpal joint restored; (f) lateral view of DRF demonstrating congruence of radiocarpal joint restored, osteosynthesis produced with LCP plate; RIA of 15.7° and RTA of 11.6°

Fig. 2 Function of the right radiocarpal joint of the 54-year-old patient K. at 3 months after surgery with sufficient range of motion

DISCUSSION

Impression fracture with typical epimetaphyseal impaction and bone and joint defect is a specific type of intra-articular injury to trabecular bone. V.G.Fedorov [21] describes specific tactics of treatment of impression fractures including (1) acute manual reduction that is often ineffective; (2) distraction is intended to improve trophics of para-articular soft tissues, prevent resorption of impacted bone, allow partial remodeling due to bone elasticity and primarily provide preoperative preparation; (3) bone grafting is normally needed to restore congruence of articular surfaces.

Intra- and paraarticular inflammatory response due to intra-articular DRF may result in arthrofibrosis, contracture and stiffness in the radiocarpal joint with external fixation considerably aggravating arthrofibrosis. For the reasons closed reduction and external fixation are contraindicated in severe intra-articular DRF. There is a need to develop surgical modalities to repair intra-articular impression fractures due to frequent failures of conservative treatment. Many authors recommend wider indications for surgical repair of intra-articular DRF including fractures with failures in congruence restoration and poor reduction [3, 10, 22].

Theoretical advantages of LCP plating as reported by Jakubietz R.G. and Gruenert J.G, 2007 [23] include: 1) simple anatomical reduction due to less cortical comminution on volar surface; 2) possibilities with early rehabilitation of upper limb and the hand; 3) less need in mechanic and occupational therapy; 4) potential relief of pain; 5) lower risk of secondary displacement; 6) decreased treatment costs. A plate fits snugly on flat volar surface and has excellent soft tissue coverage. Use of T-shaped interlocking plate in DRF has shown to reduce functional rehabilitation of the hand by 1.3 times (15.1 %) at 1 month after surgery, by 1.4 times (21.9 %) at 2 months after surgery and postoperative complications by 7.5 times (32 %) compared to T-shaped non-locking metal plate [10].

Indications for bone grafting is controversial in surgical treatment of impression intra-articular DRFs [23–26]. From one side, the radiocarpal joint bears no loading and the use of interlocking plates helps to popularise ‘blood clot’. From other side, several authors support bone grafting to avoid secondary impression due to resorption of elevated subchondral bone at early functional rehabilitation with lack of subchondral support and locking mechanism of the plate/screw interface. M.Walz et al evaluated radiological loss of correction during fracture consolidation in elderly patients with DRFs treated with conventional T-plates and fixed-angle T-plates combined with grafting. The loss of correction was significantly lower for fixed-angle plates (4.5 % vs 40.0 %) [26].

American orthopaedic suregons C. Cassedy and J.B. Jupiter evaluated closed reduction and immobilisation in two groups of patients with complicated intra-articular unstable DRFs. Patients of the first group underwent closed manual reduction with image intensifier followed by injection of a calcium-phosphate bone cement to augment metaphyseal defect. Wires were used for osteosynthesis followed by standard bracing within 2 weeks. Control subjects underwent closed reduction and application of a cast or external fixation for 6 to 8 weeks. The authors observed better results in the first group as compared to the controls at early postoperative period with improved pain and dynamometric parameters (p = 0.002). However, no clinical differences were detected at one year. Nevertheless, the cement group showed less rate of secondary impression as compared to the controls [27].

Therefore, new technologies of surgical treatment of impression intra-articular distal radius fractures showed significant benefits over standard technologies. Long-term follow-ups showed excellent and good outcomes and resultant roentgenometric parameters prevailing in patients of index group. Combined method of surgical repair of impression intra-articular distal radius fractures employing distraction module of Ilizarov external fixation, open reduction and plating coupled with new approach and modern bone substitution materials facilitates optimal roentgenometric parameters of the distal radius, use of bone grafts to prevent secondary impression providing reliable fracture fixation and early rehabilitation.

CONCLUSION

1. Impression intra-articular DRF were mostly seen in older adults and females with mean age of 48.9 ± 16.3 years. There were 14 (20.3 %) male and 55 (79.7 %) female patients. D.L.Fernandez type II fracture was most common (43.5 %).

2. RIA radiometric parameters measured 13.34° ± 0.43° in index group and 9.33° ± 0.51° (p = 0.003) in the control group at 3-month follow-up. RIA was noted to decrease in the control group and showed maximum values of 3.71° ± 0.31°, p < 0.05 at 3-month follow-up.

3. Excellent and good results were observed in index group (open reduction, plating and grafting of impression defect) at 36-month follow-up measuring DASH score of 94.2 % vs. 61.8 %, p < 0.05. No bone substitution repair was produced in controls (n = 34; 49.3 %).

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