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Comparison of three surgical methods in the treatment of intraarticular comminuted distal radius fractures: Volar locking plate, non-bridging external fixator, and bridging external fixator

Parçalı eklem içi distal radius kırıklarının tedavisinde üç cerrahi yöntemin karşılaştırılması: Volar kilitli plak, köprüsüz eksternal fiksatör ve köprülü eksternal fiksatör

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ABSTRACT

Objectives: The aim of this study was to evaluate both clinical and radiological results of intraarticular comminuted distal radius fractures treated with volar locking plate (VLP), non-bridging external fixator (NbEF), and bridging external fixator (BEF).

Patients and methods: 95 patients (44 males, 51 females; median age 49 years; interquartile range (IQR), 37 to 60 years) who were treated with VLP, NbEF, or BEF due to intraarticular comminuted distal radius fractures between January 2010 and April 2014 were evaluated retrospectively. 34 of these patients were treated with a VLP (VLP group), 30 with a NbEF (NbEF group) and 31 with a BEF (BEF group). In the final follow-up, all patients were evaluated according to clinical and radiological parameters.

Results: The median follow-up was 5 (IQR, 4 to 6) years. The VLP and NbEF groups had better results than the BEF group in terms of wrist range of motion, loss of grip strength, Green O'Brien, Mayo Modified Wrist, The Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) and VAS scores. The VLP group had the most significant radiological improvement.

Conclusion: Although clinical and radiological results for intraarticular comminuted distal radius fractures are more significantly improved in patients treated with VLP, favorable results close to VLP can be also obtained with NbEF. The BEF seems to be the least effective treatment option among the three surgical methods.

Keywords: Distal radius fracture, external fixator, volar locking plate.

ÖZ

Amaç: Bu çalışmada, volar kilitli plak (VLP), el bileğini köprülemeyen eksternal fiksatör (NbEF) ve köprüleyen eksternal fiksatör (BEF) ile tedavi edilen parçalı eklem içi distal radius kırıklarının klinik ve radyolojik sonuçları değerlendirildi.

Hastalar ve yöntemler: Ocak 2010 - Nisan 2014 arasında parçalı eklem içi distal radius kırığı nedeniyle VLP, NbEF veya BEF ile tedavi edilen toplam 95 hasta (44 erkek, 51 kadın; ortanca yaş 49; çeyrekler arası aralık (IQR) 37-60 years) yıl) retrospektif olarak değerlendirildi. Bu hastaların 34'ü VLP (VLP Grubu), 30'u NbEF (NbEF Grubu) ve 31'i BEF (BEF Grubu) ile tedavi edildi. Son kontrol vizitinde, tüm hastalar klinik ve radyolojik parametrelere göre değerlendirildi.

Bulgular: Takip süresinin ortanca değeri 5 (IQR, 4-6) yıl idi. El bilek eklemi hareket açıklığı, kavrama kuvveti kaybı, Green O'Brien, Mayo Modifiye El Bileği, QuickDASH ve VAS skorlarına göre VLP ve NbEF grupları, BEF grubuna kıyasla, daha iyi sonuçlara sahipti. Radyolojik parametrelerde en anlamlı iyileşme VLP grubunda görüldü.

Sonuç: Her ne kadar parçalı eklem içi distal radius kırıklarının klinik ve radyolojik sonuçlarında en anlamlı iyileşme VLP ile tedavi edilen erişkinlerde görülse de, NbEF ile de VLP'ye yakın olumlu sonuçlar elde edilebilir. Üç cerrahi tedavi yöntemi arasında BEF'in en az etkili seçenek olduğu görülmektedir.

Anahtar sözcükler: Distal radius kırığı, eksternal fiksatör, tedavi sonucu, volar kilitli plak.

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Distal radius fractures are the most common fractures in the whole body and constitute up to 15% of all fractures.[1,2] Multiple treatment modalities involving cast immobilization, external fixation, plating technique, and K-wire fixation are available in the management of unstable distal radial fractures.[3] The main goals of treatment are maintaining normal anatomy and obtaining a functional joint.[4] The most complicated fractures of the distal radius are high-energy, comminuted, intraarticular, and unstable fractures.

Although various surgical procedures have been described in the treatment of unstable distal radius fractures, there has been no gold standard treatment established in the literature so far.[5] Regardless of the treatment modality, the aim of the anatomical repair of distal radial articular surface should reconstitute the radial length, radial inclination, and palmar inclination.[6-8] In this respect, there is still controversy on the most optimal treatment method.

In the present study, we aimed to evaluate both clinical and radiological results of intraarticular comminuted distal radius fractures treated with volar locking plate (VLP), non-bridging external fixator (NbEF), and bridging external fixator (BEF) in adults.

PATIENTS AND METHODS

The study protocol was approved by the Şişli Hamidiye Etfal Training and Research Hospital Ethics Committee. A written informed consent was obtained from each patient. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Between January 2010 and April 2014, patients who were treated with VLP, NbEF, and BEF due to intraarticular comminuted distal radius fractures were evaluated (Figure 1-3). The patients were operated by two different surgical teams. The BEF and NEF patients were operated by an experienced team in external fixation. The VLP group was operated by a team experienced in open reduction and plate screw osteosynthesis. Inclusion and exclusion criteria are listed in Table I. Among 122 patients who met the study criteria, 27 were excluded due to lost follow-up and a total of 95 patients (44 males, 51 females; median age 49 years; interquartile range (IQR), 37 to 60 years) were retrospectively evaluated.

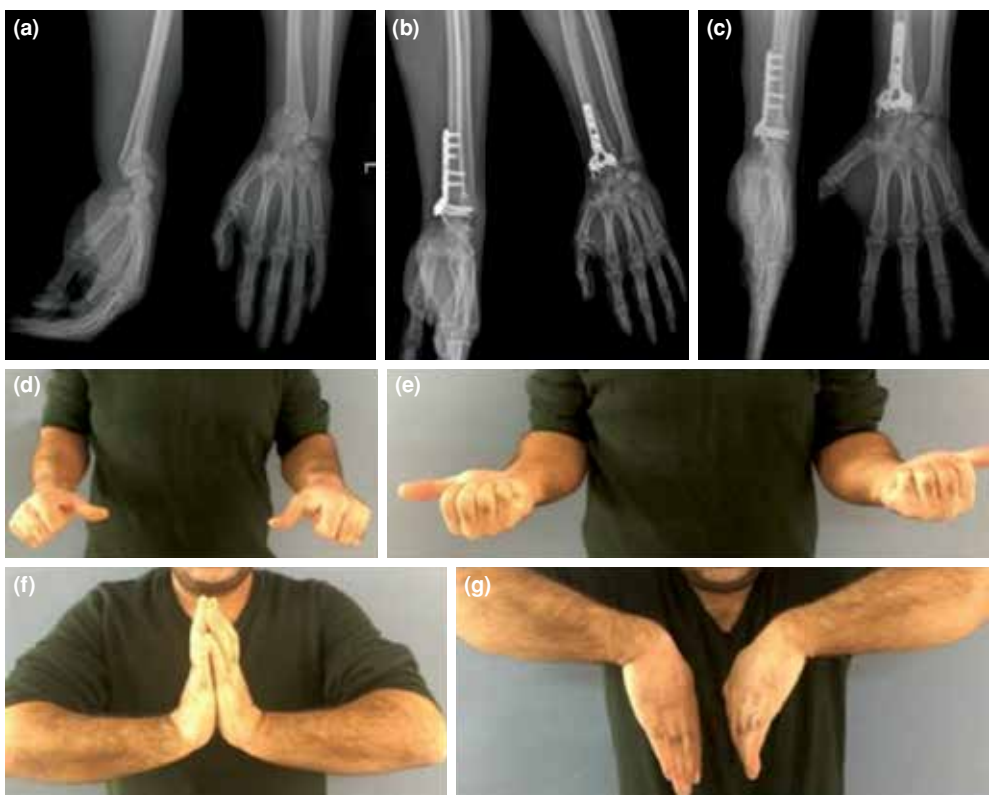

Figure 1. Pre-, early postoperative, and final follow-up radiographic images of wrist of a patient with volar locking plate **(a-c)**. The clinical picture of the patient at final follow-up **(d-g)**.

Figure 2. Pre-, early postoperative, and last follow-up radiographic images of wrist of a patient with non-bridging external fixator **(a-c)**. The clinical picture of the patient at final follow-up **(d-g)**.

The patients who were included in the study were called for a scheduled final follow-up visit. Thirty four of these patients were treated with a VLP (VLP group), 30 with a NbEF (NbEF group) and 31 with a BEF (BEF group).

Among patients who responded to our call and came to the attended to final visit, all were evaluated according to clinical and radiological parameters. The wrist range of motion values were recorded with a universal goniometer. The hand grip strength was measured and compared with the normal side, using a hand dynamometer (Baseline Digital Smedley Spring Hand Dynamometer, Park City, UT, USA) with the elbow at 90°, forearm and the wrist in neutral position. Clinical findings were evaluated according to the Green O'Brien scoring system, Mayo Modified Wrist scoring system, and Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) scoring system. The Visual Analog Scale (VAS) was used to evaluate the severity of the subjective pain. The VAS scores were determined on a scale of 0-10. Radial inclination, radial length, volar tilt and ulnar variance were evaluated radiologically.

All operations were performed under general or regional anesthesia. A pneumatic tourniquet was applied, if an open reduction had been needed and 1 gr cefazolin was used intravenously for surgical prophylaxis.

The VLP group was given immediate finger exercises with postoperative short arm splint, while two weeks later, the splints were removed and wrist movement exercises were initiated. The NEF group was given hand and wrist exercises as soon as the pain was tolerable in the first postoperative day. The NbEF group was dynamized and started motion in the wrist after three weeks, postoperatively. All fixators were removed at the 6th week postoperatively.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were

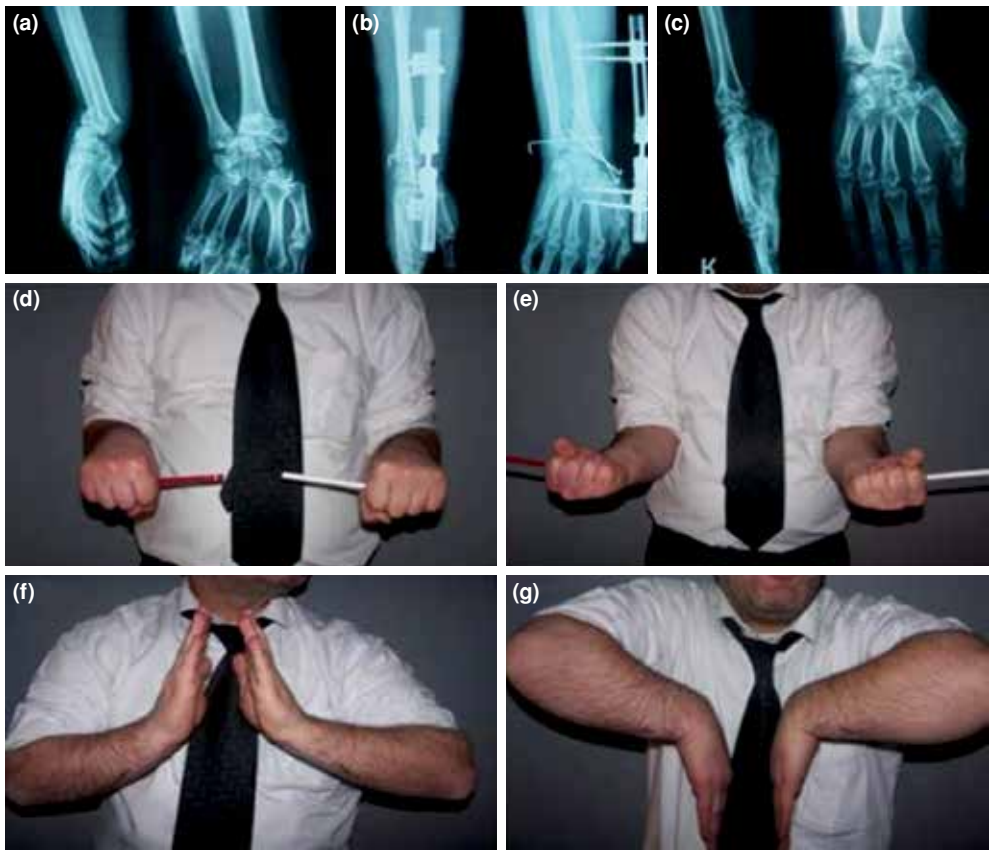

Figure 3. Pre-, early postoperative, and last follow-up radiographic images of wrist of a patient with bridging external fixator **(a-c)**. The clinical picture of the patient at final follow-up **(d-g)**.

expressed in median (IQR 25th to 75th) for numerical variables and in number and frequency for categorical variables. Numerical variables were compared using the Kruskal-Wallis and Dunn's test in more than two groups, as they did not meet the normal distribution condition. The ratios were compared using the chi-square test. A p value of <0.05 was considered statistically significant.

RESULTS

The median follow-up was 5 (IQR; 4 to 6) years. The median age of the patients was 49 (IQR; 37 to 60) years. There was no statistically significant difference in the gender distribution, affected side, rate of dominant side, fracture etiology and follow-up period among the groups (Table II). However, there was a statistically significant difference in the length of

TABLE I

Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Age ≥18 and <65 years	Bilateral fractures
Surgery within one week after trauma	Patients who has dorsal plate fixation
AO/OTA 2R3C3 type fractures	Neurovascular injury during trauma
At least 4 years of follow-up	Previous fractures or surgery history in the same upper extremity
	An injury in another part of the body at the same time
	Cognitive impairment

AO/OTA: Orthopedic Trauma Association classification system.

TABLE II

Comparisons of preoperative properties and final follow-up period

	All patients (n=95)				VLP group (n=34)				NEF group (n=30)				BEF group (n=31)				
	n	%	Median	IQR 25-75	n	%	Median	IQR 25-75	n	%	Median	IQR 25-75	n	%	Median	IQR 25-75	*p*
Age (year)																	
Gender																	0.516**
Male	44	46.3			18	52.9			14	46.7			12	38.7			
Female	51	53.7			16	47.1			16	53.3			19	61.3			
Side																	0.054**
Right	43	45.3			12	35.3			19	63.3			12	38.7			
Left	52	54.7			22	64.7			11	36.7			19	61.3			
Fracture etiology																	0.386**
Simply falling	37	38.9			8	23.5			14	46.7			15	48.4			
Falling from a high	19	20.0			9	26.5			5	16.7			5	16.1			
FFS	13	13.7			5	14.7			3	10.0			5	16.1			
Sports injury	3	3.2			3	8.8			0	0.0			0	0.0			
Industrial accident	9	9.5			4	11.8			2	6.7			3	9.7			
Beating	5	5.3			2	5.9			1	3.3			2	6.5			
Motor vehicle accident	9	9.5			3	8.8			5	16.7			1	3.2			
Length of hospital stay (days)			3	2-3			2	2-3			3	2-3			3	3-4	<0.001
Follow-up time (years)			5	4-6			5	4-6			5	4-6			5	4-6	0.935
Fracture healing time (weeks)			7	6-8			6	6-8			7	6-8			8	7-10	0.002

VLP: Volar locking plating; NEF: Non-bridging external fixator; BEF: Bridging external fixator; IQR: Interquartile range; FFS: Falling from standing.

TABLE III

Comparisons of clinical last follow-up evaluation parameters

	All patients (n=95)		VLP group (n=34)		NEF group (n=30)		BEF group (n=31)		
	Median	IQR 25-75	Median	IQR 25-75	Median	IQR 25-75	Median	IQR 25-75	*p*
Volar flexion (degrees)	70	60-80	75	65-80	75	60-80	65	50-75	0.001
Dorsiflexion ROM (degrees)	60	45-70	70	55-75	60	45-70	45	40-65	0.001
Radial deviation ROM (degrees)	15	10-20	20	15-25	15	15-20	10	5-15	<0.001
Ulnar deviation (degrees)	30	25-35	30	28.75-35	30	25-35	25	20-30	0.001
Supination (degrees)	80	75-85	80	75-90	80	75-85	75	60-80	0.002
Pronation (degrees)	80	70-85	82.5	80-90	80	75-85	75	50-80	<0.001
Loss of grip strength (%)	80	75-90	9	7-12	11	8-15	16	14-19	<0.001
Green & O'Brien score	11	8-15	90	80-95	80	75-90	80	60-90	0.020
Mayo modified wrist score	85	80-90	90	85-90	85	80-90	80	60-90	0.007
QuickDASH score	6	0-20.45	4.5	0-11.3	6	0-20.5	13	4.54-24	0.015
VAS score	1	0-2	1	0-2	1	0-2	2	1-3	0.007

VLP: Volar locking plating; NEF: Non-bridging external fixator; BEF: Bridging external fixator; IQR: Interquartile range; ROM: Range of motion; QuickDASH: Quick Disabilities of the Arm, Shoulder, and Hand, VAS: Visual analog scale.

hospital stay and fracture healing time (Table II). The volar and dorsal flexion, radial and ulnar deviation, pronation and supination angles were found to be significantly better in VLP and NbEF groups than BEF group. However, there was no statistically significant difference between VLP and NbEF groups (Tables III).

In VLP and NbEF groups, the median loss of grip strength was 9% and 11%, respectively, indicating no statistically significant difference. In both groups, the grip strength values were improved compared to BEF group. Although the most significant improvement was obtained in VLP group, there was no statistically significant difference between VLP and NbEF groups according to Green O'Brien and Mayo Modified Wrist scoring systems. Additionally, BEF group had the lowest scores in the Green & O'Brien and Mayo Modified Wrist scoring systems. According to the QuickDASH scores, the median values were obtained in VLP group with 4.5, 6, and 13 in the VLP, NbEF, and BEF groups, respectively. The median VAS scores were also statistically significantly lower in VLP and NbEF groups than BEF group. However, there was no statistically significant difference between VLP and NbEF groups (Tables III).

According to the radiological evaluation at the final follow-up visit, volar tilt, radial inclination, radial length, and ulnar variance values were found to be significantly improved in VLP group than NbEF group. Compared to BEF group, these differences were statistically significant only in radial inclination and radial length. There was also a statistically significant difference in radial length, when the BEF and NbEF were compared (Tables IV).

TABLE IV

Comparisons of radiological evaluation parameters

	All patients (n=95)		VLP group (n=34)		NEF group (n=30)		BEF group (n=31)		
	Median	IQR 25-75	Median	IQR 25-75	Median	IQR 25-75	Median	IQR 25-75	*p*
Volar tilt (degrees)	12.4	5.55-17.34	14.6	12.2-18.2	12.4	5.5-17.3	12.1	1.2-17.4	0.009
Radial inclination (degrees)	14.29	13.12-20.6	20.6	4.3-21.8	14.3	13.2-20.6	13.6	9.3-16.2	<0.001
Radial length (mm)	9.22	4.61-12.12	11.5	4.9-12.6	9.22	4.6-12.1	4.9	3.9-9.6	0.002
Ulnar variance (mm)	1	0-1	1	0.75-1.125	1	0-1	1	0-1	0.024

VLP: Volar locking plating; NEF: Non-bridging external fixator; BEF: Bridging external fixator; IQR: Interquartile range.

During follow-ups, several complications were reported in all groups. In NbEF group, pin tract infection was seen in three patients and complex regional pain syndrome (CRPS) was seen in four patients. Pin tract infections were managed with antibiotherapy and CRPS with the aid of physical therapy. In BEF group, pin tract infection was detected in three patients, CRPS in seven patients, and radial nerve sensorial branch injury in one patient. Pin tract infection and CRPS were treated as in NbEF group. However, radial nerve sensorial branch injury did not improve, despite treatment. In VLP group, two patients had flexor tenosynovitis, one patient had carpal tunnel syndrome, and two patients had CRPS. The patients with flexor tenosynovitis responded to conservative treatment. For carpal tunnel syndrome, implant extraction and carpal tunnel release surgery were performed. For CPRS, physical therapy yielded satisfactory results. Other patients in VLP group did not undergo implant extraction.

DISCUSSION

There is no conclusive evidence for which treatment method should be used in intraarticular comminuted distal radius fractures. The main advantages of external fixators (EFs) can be considered as relatively easy application, less surgical trauma, preservation of alignment and achieving acceptable reduction under fluoroscopy with the help of ligamentotaxis.[9] However, with ligamentotaxis, anatomical reconstruction of the articular surface may not be always possible. Potential side effects such as pin tract infection, joint stiffness, reduced grip strength, superficial radial nerve injury and regional pain syndrome may be seen after treatment with EFs. These complications were 33.6% in the current report[10] while it was previously reported as 62%.[11] The rate of other complications in our study is consistent with the current literature in BEF and NbEF groups. On the other hand, the advantages of VLP can be considered as early mobilization, stable and rigid fixation, and anatomic restoration of the articular surface with direct visual intervention. However, up to 12% of the patients, flexor pollicis longus rupture due to possible distal placement of the plate and screws have been reported.[12]

Previously, Egol et al.[13] reported that wrist movements were improved in patients with VLP, although this beneficial effect could be sustained only in pronation at the end of follow-up. Improved wrist movements are thought to be due to rigid fixation and early mobilization in VLP. Wheras, the NbEF systems have advantages of fragment-specific fixation, subchondral support, minimal dissection, avoidance of joint distraction and early rehabilitation.[14] However, Grewal et al.[15] reported that there was no significant difference between the EF and VLP after 12 months of follow-up. In our study, after a minimum of 4 years of follow-up, the wrist movements were improved in two early mobilization systems (VLP and NbEF). These techniques produced early wrist joint motion that is why wrist movements were improved better than BEF group.

The BEF was first described by Clyburn[16] in 1987 to reduce the final disability by starting early motion in the wrist joint. Penning et al.[17-19] also achieved successful results with BEF. In addition, Klein et al.[20] showed that dynamization at three weeks was beneficial in obtaining improved functions. Richard et al.[21] reported that patients who had VLP returned to daily life more rapidly and had improved functional outcomes than EF patients. On the contrary, Williksen et al.[22] did not found a significant difference between the VLP and EF groups in terms of functional scores over a 12-month follow-up period. Furthermore, Shukla et al.[23] reported that after one-year follow-up with EF, more favorable results were obtained, compared to VLP, and patients below 50 years of age showed improved results when treated with EF.

In our study, the loss of grip strength, the Green O'Brien, Mayo Modified Wrist, QuickDASH, and VAS scores were significantly improved in VLP and NbEF groups compared to BEF group. However, there was no significant difference when NbEF and VLP groups were compared.

In a study by Roh et al.,[24] VLP was found to be more successful in the restoration of ulnar variance and radial length, and radial inclination values were more accurately corrected with EF. However, there was no significant difference in functional results after 12 months of follow-up based on radiological values. Successful results can be obtained with BEFs in very distally localized fractures, particularly where there is no suitable place for screw placement. However, BEF is unable to stabilize the fracture as good as VLP, may not prevent collapse, and may require time to be removed. In addition, changes in palmar angulation can be observed even after EF extraction. Since open reduction and internal fixation can be performed in a direct vision of the fracture, the palmar tilt can be corrected better with VLP. In the long-term, the subchondral location of the screws in the VLP

help to prevent collapse, while supporting against palmar angulation loss.[23] In our study, the volar tilt, radial inclination, radial length, and ulnar variance were significantly restored better in VLP group. Although the radial length was restored better in NbEF group compared to BEF group, these values were not statistically significant. Other radiological parameters were not significantly different between BEF and NbEF groups. Although we believe that more favorable radiological results are not the key to achieve improved functional results, the most satisfactory radiological results were obtained in VLP group.

Nonetheless, there are some limitations to this study including its retrospective design and relatively small sample size. In addition, due to different complications of the surgical techniques, no comparison was made among the groups in terms of complications.

In conclusion, the present study suggests that, although VLP is associated with the most favorable clinical and radiological results for unstable intraarticular distal radius fractures in adults, satisfactory results close to VLP can be also obtained with NbEF. If there is an experienced team in EF application, similar clinical results to plate screw osteosynthesis can be achieved with more minimally invasive surgery. Based on our study results, we believe that if there is any fracture fragment suitable for fixation by screw or Schanz, BEF may not be the most optimal or first-line treatment option.

Declaration of conflicting interests

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