Efficacy of different fixation devices in maintaining an initial reduction for surgically managed distal radius fractures

Loren Geller, MD
Mitchell Bernstein, MD
Alberto Carli, MD
Greg Berry, MD
Rudy Reindl, MD
Edward Harvey, MD

From the Department of Surgery, Division of Orthopaedic Surgery, McGill University Healthy Centre, Montréal, Que.

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Correspondence to:
Dr. M. Bernstein
Division of Orthopaedic Surgery
MUHC — Montreal General Site
1650 Cedar Ave., Rm. L9.416
Montréal, QC H3G 1A4
fax 514 934-8394
bernstein.mitchell@gmail.com

Background: Fracture of the distal radius is a common injury. Many treatment options exist for the surgical management of extra-articular and intra-articular distal radius fractures. The best method of treatment for these fractures remains controversial. We sought to examine radiographic outcomes of patients treated with non-spanning external fixator (NSEF), open reduction and internal fixation (ORIF) with locking plates and screws or closed reduction and percutaneous pinning (CRPP) and compare their ability to maintain radiographic parameters over the initial 6-week postoperative period.

Methods: We performed a retrospective review of radiographs showing 211 distal radius fractures treated with NSEF, ORIF or CRPP. We examined the images for a variety of radiological parameters. Measurements were taken immediately postoperatively and at 6-week follow-up to determine whether there was any loss of reduction.

Results: Of the 211 fractures, 104 (49.3%) were type-A fractures, 12 (5.7%) were type-B fractures and 95 (45.0%) were type-C fractures. The 3 treatments maintained the reduction obtained at surgery until healing. The CRPP and ORIF treatments failed to maintain correction in ulnar variance for the 6-week period; however, only ORIF actually changed the ulnar variance from presurgical values.

Conclusion: Treatment with ORIF for comminuted, intra-articular distal radius fractures produces good radiographic results with maintenance of surgical radiographic parameters, whereas NSEFand CRPP of less complex fractures also provide good results. This suggests that fracture-specific fixation with CRPP or NSEF are sufficient for certain distal radius fractures.

Contexte : La fracture de la partie distale du radius est une blessure courante. Il existe de nombreuses façons possibles de traiter chirurgicalement les fractures de la partie distale extra-articulaire et intra-articulaire du radius, et ce qui constitue la meilleure façon de traiter ces fractures suscite toujours la controverse. Nous avons cherché à étudier par radiographie les résultats des patients traités par fixateur externe non recouvrant (NSEF), réduction ouverte et fixation interne (ORIF) avec plaques et vis de blocage, ou réduction fermée et pose de broches percutanées (CRPP), et à comparer la capacité à maintenir des paramètres radiographiques au cours des 6 premières semaines suivant l'intervention.

Méthodes : Nous avons procédé à une étude rétrospective de radiographies illustrant 211 fractures de la partie distale du radius traitées par les techniques NSEF, ORIF ou CRPP. Nous avons étudié les images pour rechercher tout un éventail de paramètres radiologiques. On a pris des mesures immédiatement après l'intervention et au suivi à 6 semaines afin de déterminer s'il y avait perte de réduction.

Résultats : Sur les 211 fractures, 104 (49,3 %) étaient de type A, 12 (5,7 %), de type B et 95 (45,0 %), de type C. Les 3 traitements ont maintenu la réduction réalisée au moment de l'intervention chirurgicale jusqu'à la guérison. Les techniques CRPP et ORIF n'ont pas maintenu la correction de la variation cubitale pendant la période de 6 semaines, mais seul le traitement ORIF a effectivement modifié la variation cubitale par rapport aux valeurs préchirurgicales.

Conclusion : Le traitement par la technique ORIF des fractures intra-articulaires et comminutives de la partie distale du radius produit de bons résultats radiographiques et maintient les paramètres radiographiques chirurgicaux; les techniques NSEF et CRPP de réduction des fractures moins complexes produisent aussi de bons résultats. Cela indique que la fixation spécifique à la fracture au moyen des techniques CRPP ou NSEF suffit pour certaines fractures de la partie distale du radius.

Fracture of the distal radius in adults is one of the most common sites of injury. Many of these fractures are intra-articular.[1,2] Whereas a large number of these fractures are managed nonoperatively, the number of patients who undergo surgical management is considerable. Certainly, the advent of new low-profile plates and locking systems has popularized the surgical option. A myriad of treatment modalities exist for surgical management of these fractures, including open reduction and internal fixation (ORIF) with volar or dorsal plates and screws, nonspanning external fixation (NSEF), closed reduction and percutaneous pinning (CRPP), spanning external fixators or a variation of each.[3–9]

Functional outcome after surgical management of distal radius fractures has been related to bony anatomy and the ability to maintain reduction until osseous healing.[1,10–14] Often, different procedures are chosen based on the fracture pattern and/or the presence of an intra-articular fracture extension,[3–6,15] depending on surgeon choice. Despite the number of options available for treatment of these common fractures, no one modality has proven to be superior. Specifically, few studies compare nonspanning external fixation with other treatment options.[8,16–18] In addition, there are limited comparative studies examining the role of locking plates in distal radius fractures.

The purpose of this study was to examine radiographic outcomes of patients treated with ORIF, CRPP and NSEF and compare their ability to maintain radiographic parameters over the initial 6-week postoperative period. This is appropriate since functional outcome has already been established to correlate with radiographic findings. This study was also designed to be a pilot review for the 3 most common surgical options of extra-articular fractures to determine whether a larger randomized prospective study is warranted or feasible. There is little in the literature to suggest the best sample size for a 3-armed randomized study of these treatment modalities.

Methods

We obtained hospital and university institutional review board approval before beginning the study. In all, we identified 267 distal radius fractures treated operatively between January 2000 and December 2006 at a tertiary-care university hospital. One of 3 fellowship-trained trauma orthopedic surgeons (G.B., R.R., E.H.) performed the surgeries. All patients underwent a trial of closed reduction and casting in the emergency department. The decision to operate was made by the operating surgeon after the initial reduction or at the 1-week follow-up. We chose the radiographic evidence of failure based on the presence of 1 or more previously described imaging findings of instability:[19,20]

1. initial dorsal angulation greater than 20°,
2. more than 1 mm intra-articular displacement,
3. dorsal cortex comminution,
4. age older than 60 years,
5. associated ulna fracture,
6. initial shortening greater than 5 mm, and
7. loss of reduction demonstrated on follow-up radiographs.

The operating surgeon determined the best device for fixation of the particular fracture type. The locking plates used in the study were 2.4 mm from the distal radius locking set (Synthes). The nonspanning external fixator was a small external fixator from Synthes. The surgeons did the percutaneous pinning according to the Kapandji technique, using 1.6 mm k-wires.

We classified each patient's fracture using the AO and Melone classification schemes for distal radius fractures,[21–23] with consensus obtained among 3 observers (L.G., M.B., E.H.). However, only the AO classification scheme had sufficient interobserver reliability to use for data analysis. We did not use the Melone classification scheme in final data analysis owing to disagreement among the observers; regarding the AO classification, 2 of the 3 observers agreed on the classification proposed before it was deemed final. Classification occurred retrospectively but before data analysis.

Box 1. Radiographic measurements

Posteroanterior projection

- Radial inclination
- Radial length
- Radial shift
- Ulnar variance
- Articular steps
- Articular gaps

Lateral projection

- Palmar tilt
- Dorsal shift
- Articular steps
- Articular gaps

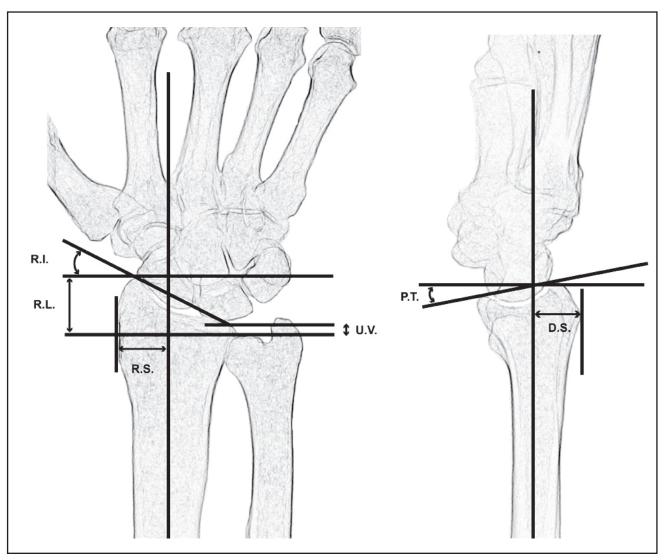

Fig. 1. Posteroanterior and lateral diagram showing radiographic measurements as described by Kreder et al.[24]

Radiographic follow-up

Appropriate radiographs were avilable for 211 fractures (79%) in 206 patients who underwent NSEF, ORIF or CRPP. We scrutinized the patients' preoperative and postoperative radiographs for several radiographic parameters.[24,25] These specific measurements are detailed in Box 1 and are shown in Figure 1. We measured radiographic parameters from images obtained in the operating room or on postoperative day 1 or 2. The operating room images were fluoroscopic films. All films were standard radiographs for viewing the distal radius (posteroanterior, lateral, oblique).

Statistical analysis

We performed our statistical analysis using SPSS software (SPSS Inc.). We analyzed continuous variables pertaining to implant types using 2-tailed paired *t* tests, and we compared categorical variables using χ^2 and Fisher exact tests where applicable. We adjusted α values according to repeated measurements to avoid type-1 errors. For example, we set the α at 0.005 for the paired *t* tests.

RESULTS

In total, we examined 206 patients' files (211 fractures). The demographic results are sumarized in Table 1. Of the fractures, 104 (49.3%) were AO type-A fractures, 12 (5.7%) were AO type-B fractures and 95 (45.0%) were AO type-C fractures. The different fracture classifications are summarized in Table 1.

We recorded postoperative measurements from radiographic examination. The fractures were not similar among the NSEF, ORIF or CRPP groups owing to a nonrandomized bias. Overall, we found correction immediately after surgery in most radiographic parameters (Tables 2–4). We compared postoperative radiographic measurements with those from the 6-week follow-up radiographs to observe how well the fixations were able to maintain the reductions during that time period. We performed a subgroup analysis that revealed that there was no significant change in the CRPP group, but the ulnar variance drifted from ulnar-neutral to +1 (Table 5). There was no significant difference between the immediate postoperative radiographs and the 6-week follow-up radiographs in all parameters for the group treated with NSEF (Table 6). Finally, ORIF held all measurements except ulnar variance, which progressed from –1 to ulnar-neutral, a 1-mm loss of reduction (Table 7).

DISCUSSION

Functional results of distal radius fractures have been shown by several authors to correspond to the degree of anatomic reduction of the fracture.[10,12,26,27] No method of achieving and maintaining this bony position has proven

Table 1. Characteristics of patients who underwent 1 of 3 types of surgical repair for a distal radius fracture

Characteristic	Method of fixation: ORIF	CRPP	NSEF	Total
No. of patients	107	74	30	211
Male:female ratio	50:57	28:46	6:24	84:127
Age, mean (SD) yr	51.2 (17–87)	55.7 (22–97)	59.4 (19–86)	53.9 (17–97)
AO fracture type				
23A	29	50	25	104
23B	10	2	0	12
23C	68	22	5	95

CRPP = closed reduction percutaneous pinning; NSEF = nonspanning external fixator; ORIF = open reduction internal fixation; SD = standard deviation.

Table 2. Open reduction and internal fixation: mean preoperative versus postoperative radiographic parameters

Parameter	Mean (SD): Preoperative*	Mean (SD): Postoperative†	95% CI	*p* value‡
Radial inclination, °	18.7 (4.1 to 38.4)	20.7 (4.0 to 31.0)	–3.36 to –0.60	0.005
Radial length, cm	0.9 (–1.0 to 2.6)	1.1 (0.0 to 2.1)	–0.33 to –0.13	< 0.001
Ulnar variance, cm	0.1 (–0.8 to 1.0)	–0.1 (–0.5 to 0.6)	0.15 to 0.25	< 0.001
Palmar tilt, °	1.6 (–28.0 to 41.3)	–3.1 (–15.7 to 16.2)	2.13 to 7.25	< 0.001§
PA articular				
Steps, cm	0.1 (0.0 to 0.7)	0.0 (0.0 to 0.3)	0.04 to 0.09	< 0.001
Gaps, cm	0.1 (0.0 to 2.0)	0.0 (0.0 to 0.4)	0.04 to 0.13	0.001
Lateral articular				
Steps, cm	0.1 (0.1 to 0.7)	0.0 (0.0 to 0.3)	0.02 to 0.07	< 0.001
Gaps, cm	0.1 (0.0 to 0.9)	0.0 (0.0 to 0.4)	0.06 to 0.14	< 0.001

CI = confidence interval; PA = posteroanterior; SD = standard deviation.
*After reduction.
†After fixation.
‡Adjusted statistical significance $p < 0.005$.
§Denotes the only parameter that was significantly changed with surgery: palmar tilt.

Table 3. Nonspanning external fixation: mean preoperative versus postoperative radiographic parameters

Parameter	Mean (SD): Preoperative*	Mean (SD): Postoperative†	95% CI	*p* value‡
Radial				
Inclination, °	19.5 (8.8 to 33.0)	20.8 (12.1 to 31.5)	–4.01 to 1.43	0.34
Length, cm	0.9 (0.2 to 1.9)	1.1 (0.3 to 2.4)	–0.32 to 0.02	0.09
Shift, cm	1.8 (0.9 to 2.6)	1.8 (1.1 to 2.4)	–0.13 to 0.21	0.63
Ulnar variance, cm	0.2 (–0.3 to 1.8)	–0.1 (–2.9 to 0.5)	0.02 to 0.45	0.07
Palmar tilt, °	–2.8 (–20.6 to 15.8)	–8.8 (–19.9 to 3.7)	2.13 to 9.89	0.004§
Dorsal shift, cm	1.0 (0.4 to 1.9)	0.9 (0.0 to 1.8)	–0.82 to 0.27	0.29

CI = confidence interval; N/A = not applicable; SD = standard deviation.
*After reduction.
†After fixation.
‡Adjusted statistical significance $p < 0.005$.
§Denotes the only parameter that was significantly changed with surgery: palmar tilt.

Table 4. Closed reduction and percutaneous pinning: mean preoperative versus postoperative radiographic parameters

	Mean (SD)				
Parameter	Preoperative*		Postoperative†		95% CI	*p* value‡

Parameter	Preoperative*		Postoperative†		95% CI	*p* value‡
Radial inclination, °	21.0	(3.4 to 31.0)	21.5	(10.0 to 38.3)	–1.78 to 0.82	0.46
Ulnar variance, cm	0.1	(–0.5 to 2.0)	0.0	(–0.5 to 0.6)	0.15 to 0.25	0.044
Palmar tilt, °	–0.8	(–35.0 to 30.0)	–5.5	(–20.9 to 5.3)	2.03 to 7.45	0.001
PA articular						
Steps, cm	0.0	(0.0 to 0.2)	0.0	(0.0 to 0.2)	–0.01 to 0.01	0.87
Gaps, cm	0.0	(0.0 to 0.4)	0.0	(0.0 to 0.4)	–0.02 to 0.03	0.78
Lateral articular						
Steps, cm	0.0	(0.0 to 0.3)	0.0	(0.0 to 1.1)	–0.04 to 0.02	0.41
Gaps, cm	0.0	(0.0 to 0.9)	0.0	(0.0 to 0.8)	–0.04 to 0.01	0.30

CI = confidence interval; PA = posteroanterior; SD = standard deviation.
*After reduction.
†After fixation.
‡Adjusted statistical significance $p < 0.005$.

Table 5. Closed reduction and percutaneous pinning: mean postoperative versus 6–week radiographic parameters

Parameter	Mean (SD) Postoperative		Mean (SD) 6–week follow–up		95% CI	*p* value*
Radial						
Inclination, °	21.5	(10.0 to 38.3)	21.7	(0.1 to 32.7)	–1.22 to 0.75	0.63
Length, cm	1.0	(0.0 to 1.7)	1.0	(–0.7 to 1.7)	–0.44 to 0.12	0.37
Shift, cm	1.7	(1.0 to 2.9)	1.7	(1.1 to 3.0)	–0.10 to 0.03	0.30
Ulnar variance, cm	0.0	(–0.5 to 0.6)	0.1	(–0.5 to 1.0)	–0.14 to 0.06	< 0.001
Palmar tilt, °	–5.5	(–20.9 to 5.3)	–6.0	(–22.7 to 10.0)	–1.30 to 2.06	0.65
Dorsal shift, cm	1.1	(0.5 to 1.9)	1.1	(0.5 to 1.9)	–0.11 to 0.07	0.66
PA articular						
Steps, cm	0.0	(0.0 to 0.2)	0.0	(0.0 to 0.0)	–0.00 to 0.01	0.32
Gaps, cm	0.0	(0.0 to 0.4)	0.0	(0.0 to 1.7)	–0.05 to 0.03	0.61
Lateral articular						
Steps, cm	0.0	(0.0 to 1.1)	0.0	(0.0 to 0.4)	–0.02 to 0.04	0.50
Gaps, cm	0.0	(0.0 to 0.8)	0.0	(0.0 to 0.7)	–0.01 to 0.02	0.58

CI = confidence interval; PA = posteroanterior; SD = standard deviation.
*Adjusted statistical significance $p < 0.005$.

Table 6. Nonspanning external fixation: mean postoperative versus 6–week radiographic parameters

Parameter	Mean (SD) Postoperative		Mean (SD) 6–week follow–up		95% CI	*p* value*
Radial						
Inclination, °	20.8	(12.1 to 31.5)	21.1	(10.0 to 31.0)	–2.52 to 1.87	0.76
Length, cm	1.1	(0.3 to 2.4)	1.1	(–0.3 to 1.7)	–0.10 to 0.20	0.52
Shift, cm	1.8	(1.1 to 2.4)	1.7	(1.1 to 2.7)	–0.9 to 0.19	0.45
Ulnar variance, cm	–0.1	(–2.9 to 0.5)	0.1	(–0.4 to 0.8)	–0.38 to 0.02	0.08
Palmar tilt, °	–8.8	(–19.9 to 3.7)	–10.0	(–21.9 to 4.0)	–2.14 to 4.54	0.47
Dorsal shift, cm	0.9	(0.0 to 1.8)	0.9	(0.4 to 1.6)	–0.10 to 0.17	0.57
PA articular						
Steps, cm	0.0	(0.0 to 0.0)	0.0	(0.0 to 0.2)	–0.00 to 0.01	0.33
Gaps, cm	0.0	(0.0 to 0.4)	0.0	(0.0 to 0.3)	–0.01 to 0.05	0.14
Lateral articular						
Steps, cm	N/A		N/A		N/A	N/A
Gaps, cm	0.0	(0.0–0.3)	0.0	(0.0–0.4)	–0.07 to 0.01	0.19

CI = confidence interval; N/A = not applicable; PA = posteroanterior; SD = standard deviation.
*Adjusted statistical significance $p < 0.005$.

superior, which in part explains the numerous treatment modalities that have been described for simple to complex distal radius fractures. Recently, retrospective and prospective clinical trials have been published to address this issue; however, they included spanning external fixators augmented with percutaneous k-wire fixation.[28,29] McQueen[7] has already demonstrated in her randomized study that NSEF was superior to spanning external fixation with pinning in patients who lost acceptable reductions of their distal radius fractures. Therefore, NSEF may be the gold standard against which other modalities should be compared. Other review articles have also attempted to determine the best mode of fixation, yet there is still no conclusion as to which method is superior.[30,31] To our knowledge, there have been no studies that directly compared NSEF, ORIF and CRPP.

More than 60% of the fractures in the ORIF group were AO type-C fractures. These were the most severe injuries with the most comminution and energy; however, the overall radiographic outcome associated with ORIF was very similar to that with NSEF and CRPP, which were used for less complex injury patterns.[32] In type-C fractures, anatomic reconstruction of the articular surface is of prime importance.[3,4,6,33] As shown in Table 7, articular congruency was improved from a mean of 1 mm (posteroanterior steps, posteroanterior gaps, lateral steps, lateral gaps) to a mean of 0 mm postoperatively. Treatment with ORIF was able to correct all measurements of articular incongruency except ulnar variance when comparing pre- and postoperative radiographs. The correction in articular congruency was maintained at the 6-week follow-up. Patients were treated with volar or dorsal locked plates in almost 60% of cases; however, it is still unknown whether this system is best for treating distal radius fractures. Thus, the optimal position and plating system should be determined by conducting prospective randomized trials before widespread acceptance.[34]

Thirty patients underwent NSEF, which was used almost exclusively for AO type-A fractures. AO type-C fracture patterns were treated in this manner only 5 times. The NSEF method was devised and has been promoted as a way to provide a less invasive treatment of unstable metaphyseal distal radius fractures.[8] Literature contends that it allows direct correction of palmar tilt.[8,33] Our study supports that contention (Table 3); however, it was the only radiological parameter that was changed by surgery. For palmar tilt there was no significant change at 6 weeks compared with the immediate postoperative film (p = 0.47). There was no significant change in any other radiographic measurements from the postoperative to the 6-week follow-up radiographs, indicating that the NSEF was able to hold the reduction during this period. This is to be expected, as no other parameters were actually changed by surgery with NSEF. This is biased by the fact that most patients had a good reduction in cast before surgery, and it was the cast radiograph that was used to determine the reduction efficacy. The ability to retain a reduction was the outcome tested in this group. Arguably, spanning external fixation is a more common surgical technique used for distal radius fractures, but it is less efficacious in both obtaining and maintaining a reduction.[8,16,17,35–37]

Table 7. Open reduction and internal fixation: mean postoperative versus 6–week radiographic parameters

Parameter	Mean (SD) Postoperative	Mean (SD) 6–week follow–up	95% CI	*p* value*
Radial				
Inclination, °	20.7 (4.0 to 31.0)	21.7 (9.9 to 40.0)	–2.10 to –0.10	0.032
Length, cm	1.1 (0.0 to 2.1)	1.2 (0.2 to 12.0)	–0.27 to 0.17	0.64
Shift, cm	1.7 (0.2 to 3.1)	1.7 (0.8 to 2.5)	–0.06 to 0.11	0.59
Ulnar variance, cm	–0.1 (–0.5 to 0.6)	0.0 (–0.5 to 0.7)	–0.11 to –0.04	< 0.001
Palmar tilt, °	–3.1 (–15.7 to 16.2)	–1.6 (–15.0 to 22.5)	–2.70 to –0.43	0.007
Dorsal shift, cm	1.1 (0.0 to 2.2)	1.1 (–0.3 to 2.1)	–0.11 to 0.13	0.10
PA articular				
Steps, cm	0.0 (0.0 to 0.3)	0.0 (0.0 to 0.2)	–0.05 to 0.00	0.19
Gaps, cm	0.0 (0.0 to 0.4)	0.0 (0.0 to 0.4)	–0.01 to 0.02	0.59
Lateral articular				
Steps, cm	0.0 (0.0 to 0.3)	0.0 (0.0 to 0.2)	–0.01 to 0.01	0.89
Gaps, cm	0.0 (0.0 to 0.4)	0.0 (0.0 to 0.5)	–0.02 to 0.02	0.74

CI = confidence interval; PA = posteroanterior; SD = standard deviation.
*Adjusted statistical significance $p < 0.005$.

Seventy-four patients in our study underwent CRPP, and most of their fractures (68%) were AO type-A fractures. Both ORIF and CRPP groups were not able to maintain the correction in ulnar variance from the immediate postoperative to 6-week follow-up radiographs; the CRPP group was not able to obtain such a reduction in the operating room (Table 4). Although CRPP failed to obtain or maintain ulnar variance, the loss was only 1 mm and may have little or no clinical importance. The change in ulnar variance during the 6 weeks after surgery for ORIF was similarly 1 mm. Because the immediate postoperative film was taken in the operating room, the perfect posteroanterior and lateral projection could be obtained. This probably was not the case with the 6-week follow-up taken by a radiograph technician in the clinic. The difference in radograph projection adds a certain measure of error to this study. However, this error is present throughout the study and cannot be used to explain loss of fixation in 1 group and 1 radiographic parameter. Another weakness of the study is that it is retrospective and is neither blinded nor randomized. It is difficult to state an overall best fixation device from this study; the fractures were not similar among the groups owing to a nonrandomized bias. One might argue that these fractures are very different and will behave differently in terms of radiographic and functional outcome. However, the fixation device used was judged by the experienced operating surgeon to be the best method available for the fracture type. As such, we would expect radiographic outcome to be fairly accurate, and thus we expect the fractures to stay reduced.

All 3 fixation techniques used in this study show an ability to maintain reduction for the initial 6-week period after surgery. The fact that ORIF was used in patients with more serious fractures with articular incongruity and comminution would lead one to believe that this is the most versatile and useful technique. There is a definite need for a randomized prospective stratified study to determine which modality is the best.

Competing interests: None delcared.

Contributors: Drs. Geller, Berry, Reindl and Harvey designed the study. Drs. Geller, Bernstein, Carli, Berry and Reindl acquired the data, which Drs. Geller, Bernstein, Carli and Harvey analyzed. Drs. Geller, Bernstein and Harvey wrote the article, which Drs. Bernstein, Carli, Berry, Reindl and Harvey reviewed. All authors approved publication.

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