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Research Article

Techniques and Constructs to Achieve Radioscapholunate Fusion: A Systematic Review

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1. Abstract

1.1. Background: Radioscapholunate (RSL) arthrodesis addresses radiocarpal-arthrosis while maintaining midcarpal motion. This procedure has incorporated various fixation constructs and modifications with no consensus of superiority in literature. The purpose of this study is to systematically review outcomes of 1) RSL arthrodesis constructs and approach; 2) Distal pole scaphoid (DSE) and triquetrum excision (TE).

1.2. Methods: A systematic review of the literature was performed for all articles published until March 2022. EMBASE, PubMed, Medline Ovid and Cochrane Databases were searched for articles assessing techniques and fixation constructs for performing an RSL arthrodesis. Two independent reviewers assessed the articles for inclusion criteria, with disagreements resolved by consensus. Outcomes included range of motion, union rates, midcarpal contact pressure, complication rates, and patient satisfaction.

1.3. Results: 122 articles were screened, with sixteen studies included for final review. Studies addressed 1) type of fixation construct 2) DSE 3) TE. The clinical studies (n=16 patients) reported no differences in fusion rates between distal radius Pi plate and headless compression screws (HSC), while biomechanical studies (n=2) report no significant difference in load to failure. DSE improved range of motion, union rates, and time to union by 5 months ($p<0.001$). In cadaver models, TE with DSE improved ROM and decreased midcarpal contact pressures compared to DSE alone, but the clinical studies did not demonstrate significant difference in union rates or range of motion ($p=0.3$).

1.4. Conclusion: Various constructs are used for RSL arthrodesis with no clear superiority. DSE can improve union rates and range of motion, but further clinical studies are needed to demonstrate benefits of TE.

2. Introduction

Arthritis of the wrist is a painful condition that can have various causes and presentations. The wrist is particularly susceptible to posttraumatic arthritis secondary to the high prevalence of distal radius injuries, which accounts for roughly 18% of all fractures in adult patients [1]. Other etiologies include osteoarthritis, septic arthritis, Madelung deformities, inflammatory arthropathies, as well as other less known entities (eg. Kienbock's disease) [2]. Pain from wrist arthritis can be debilitating and significantly affect a patient's ability to perform their activities of daily living. The primary goal of treatment is to provide the patient with a pain free, stable wrist joint.

In many common forms of arthritis, the radiolunate articulation is spared, which allows for surgical options such a proximal row carpectomy or scaphoid excision with 4 corner fusion [2]. When the radiolunate articulation is involved, however, options tend to be more limited and include RSL (radioscapholunate) arthrodesis, total wrist arthroplasty, total wrist arthrodesis, or partial wrist denervation [2]. Many of these procedures come at the cost of loss of wrist ROM, loss of normal wrist kinematics, or are not robust enough to meet the demands of more active patients [3].

Functional wrist motion required to perform ADLs has been described as 35 degrees of extension, 5 degrees of flexion, 15 degrees of ulnar deviation, and 10 degrees of radial deviation [3]. In order to preserve motion and maintain function, surgeons have attempted to perform procedures such as total wrist arthroplasty in patients with radio-carpal arthritis. TWA can provide good pain relief, how-

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ever early loosening and variable 5-year survival rates makes this procedure best suited for low demand, elderly patients. More durable procedures that allow for maintenance of motion without destabilization of the midcarpal joint are needed as an alternative to total wrist arthroplasty or total wrist arthrodesis.

Radioscapholunate arthrodesis was first described in 1955 by Watson-Jones for radiocarpal degeneration from posttraumatic arthritis, RA, and Kienböck's disease [5]. This technique fuses the arthritic radiocarpal joints while maintaining midcarpal motion [4]. Over time, this procedure has been modified to include excision of the distal pole of the scaphoid with or without triquetrum excision. These newer techniques aim to reduce impingement and improve overall motion without destabilizing the midcarpal joint, and indications for these procedures continue to expand [2]. However, there is an apparent lack of literature comparing these techniques. The aims of this systematic review were to compare the use of RSL arthrodesis vs. RSL arthrodesis with distal pole of the scaphoid excision vs. RSL arthrodesis with distal pole of the scaphoid excision and triquetrum excision in terms of patient outcomes, maintenance of wrist ROM, and midcarpal contact pressures. We also aimed to discuss different surgical techniques regarding the construct for fusion as well as surgical approach.

3. Materials and Methods

3.1. Search Strategy

We performed a systematic review following the guidelines outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Two independent reviewers (AA, SR) in duplicate searched the EMBASE, PubMed, Medline Ovid and Cochrane Database from inception until March 2022 using the search terms (Rasioscapholunate AND Arthrodesis) in all possible combinations.

3.2. Study Screening

All titles, abstracts, and full texts were screened in duplicate by two reviewers (AA, SR) to assess all potential studies for eligibility. Any disagreements at the title and abstract stages were discussed among the reviewers and resolved by the senior author. Consensus was reached for final eligibility of all articles. The references for each of the articles were also assessed to ensure no additional studies were falsely excluded from the systematic review.

3.3. Assessment of Study Eligibility

We defined inclusion and exclusion criteria for this systematic review a priori. Inclusion criteria were studies 1) in English, 2) on humans 3) specifically reported on a described a technique for performing a radioscapholunate arthrodesis and described a particular outcome in primary osteoarthritis or post traumatic arthritis or other pathology. We included clinical and biomechanical studies into our review. Exclusion criteria consisted of papers that did not describe the specific technique used, exclusively focused on patients with rheumatoid arthritis or other systemic diseases, included other co-dominant procedures during the arthrodesis (ex ulnar sided procedures), and not in English. The primary outcome of interest was comparing various techniques for performing RSL arthrodesis, the secondary outcome was reviewing outcomes of distal pole scaphoid or triquetrum excision.

4. Results

4.1. Study Identification

The results are synthesized in (Figure 1). In total 122 total articles were identified in a total of three databases. In total 37 duplicates were removed and 1 was removed as not being available in English resulting in a total of 84 articles to review. The first level of screening consisted of an assessment of titles and abstract to identify all potentially relevant studies. After screening, 68 records were excluded, thus leaving a total of 16 full text articles assessed for eligibility. A thorough full-text assessment of these studies was then performed to ensure they met all inclusion criteria. Any disagreements were resolved by the senior author (JRL). The various study designs as well as the number of patients or cadaveric specimens of the selected articles are summarized in (Table 1).

Table 1: A comparison of the study designs and patient demographics in the selected articles. RSL = radioscapholunate, DSE = distal pole scaphoid excision, TE = triquetrum excision, ROM = range of motion, HCS = headless compression screw.

Study	Design	Demographics
Shin et al 2007	Retrospective cohort, Technique paper, no control, RSL arthrodesis with iliac crest bone graft.	5 patients
Fakunle et al 2021	Systematic review	274 patients, RSL Arthrodesis had 180 patients (49% female)
Quadlbauer et al 2017	Retrospective cohort, no control; technique paper; volar approach after distal radius malunion with DSE	14 patients
Isaacs et al 2008	Biomechanical; load to failure, circular vs T plate	10 cadavers, 20 wrists.
Galvis et al 2013	Retrospective cohort, no control, technique paper, no DSE	7 patients, 5M 2F
Biswas et al 2013	Retrospective cohort, technique paper no control, all DSE	9 patients
Shapiro et al 2020	Biomechanical; Distraction of HCS vs plate/screw vs pin plate	27 cadavers
Sraj et al 2010	Retrospective cohort, technique paper, no control	32 patients
Mühldorfer-Fodor et al 2012	Retrospective cohort, RSL arthrodesis with and without DSE	61 patients

Holleran et al 2013	Biomechanical; Contact pressure RSL arthrodesis with and without distal scaphoid excision	8 cadavers
Pervaiz et al 2009	Biomechanical; Wrist ROM of Control vs RSL arthrodesis vs RSL w/ DSE vs RSL w/ DSE and triquetral excision	10 cadavers
Bain et al 2014	Biomechanical; Wrist ROM of Control vs RSL fusion vs RSL w/ DSE vs RSL w/ DSE and TE	12 cadavers; memory staples for RSL fusion.
Ha et al 2018	Prospective cohort; outcomes RSL fusion vs RSL w/ DSE vs RSL w/ DSE and TE	17 patients w/ 10 year follow up
Leichti et al 2019	Case report, technique paper; RSL arthrodesis with TE in post traumatic RC arthritis with ulnar impaction	1 patient (1M)
McNary et al 2019	Biomechanical; contact pressure capitolunate joint after RSL arthrodesis with DSE and TE	10 cadavers
Suzuki et al 2021	Biomechanical; Dart throwing in control vs RSL arthrodesis w/ and w/out DSE and TE	7 Cadavers (2M 5F)

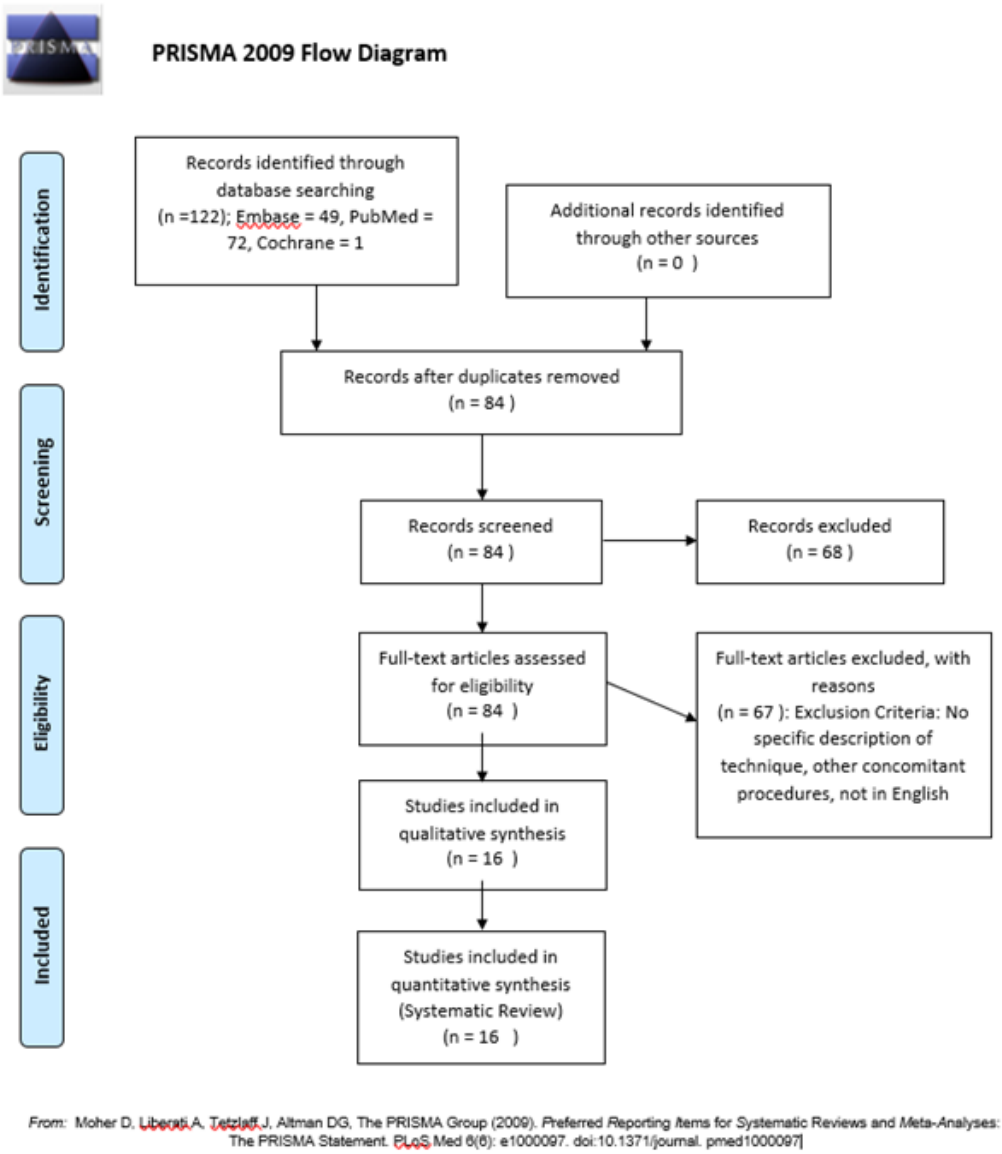

Figure 1: PRISMA flow diagram demonstrating screening and review process with final article selection.

4.2. Volar Approach

Our review discovered only one study that primarily used a volar approach, with has the advantage of being able to remove previously placed hardware at the same time. This study [6, 7] was a retrospective cohort of 14 patients who sustained a malunion following a distal radius fracture and subsequent arthrosis. The authors used a traditional volar approach or through the pre-existing incision, and resected the distal quarter of the scaphoid. Final fixation consisted of polyaxial 2.3mm locking frame. The results were promising with no incidence of non union or infections with patients achieving 80% grip strength compared to the contralateral side.

4.3. Fixation Constructs

The studies comparing various fixation constructs are summarized in (Table 2), with the inclusion of whether the distal pole of the scaphoid or triquetrum was excised in the author's described technique. The two clinical studies [8-10] compare a distal radius Pi plate and cannulated compression screws. Both studies employed the use of autologous bone graft and demonstrated successful results with all patients in the cohorts achieving union. Although the post operative range of motion is not reported in Biswas et al 2013, that reported in the Galvis et al 2013 study that employs headless compression screws appears to be similar to other studies that also excised the distal pole of the scaphoid [12, 13]. Despite this success, one of the biomechanical studies [11] demonstrated significantly greater distraction across the radioscapholunate interval in a cadaveric model with the use of headless compression screw compared to other fixation constructs. Whether or not this difference would clinically impact union rates remains to be answered, as patients are typically immobilized post operatively to some degree thus mitigating this risk.

Table 2: A comparison of the studies addressing various fixation constructs for RSL arthrodesis.

Study	Fixation	Outcome Measure	Outcomes
Isaacs et al 2008	Peek-optima circular plate vs Stainless steel oblique 3.5mm T-plate, no scaphoid excision.	Biomechanical: Cycles of flexion and extension until failure	No significant difference between load to failure
Galvis et al 2013	Distal Radius Pi Plate, iliac crest bone graft, no scaphoid excision.	Clinical: Union rates, range of motion	All patients achieved union mean 7 weeks (range 6-10 wks) ROM: 52 deg flex/ext; 12/10 deg radial/ulnar deviation.
Biswas et al 2013	Cannulated headless compression screw with distal radius autologous bone graft, distal scaphoid excision.	Clinical: Union rates, midcarpal arthrosis	All patients achieved union at follow up No cases of midcarpal arthrosis at 12 month follow up.
Shapiro et al 2020	-Cannulated headless compression screw -Radioscapholunate fusion plate -Dorsal ulnar pin plate -DSE and TE in all models.	Biomechanical: 5,000 cycles of flexion and extension, distraction across RSL articulation	HCS Distraction: 1.49 +/- 1.52 mm Fusion plate:0.18 +/- 0.25 mm Dorsal ulnar pin-plate: 0.28 +/- 0.26 -Significantly greater distraction across RSL in HCS vs other groups.

4.4. Distal Pole Scaphoid Excision

In regards to the outcomes of excision of the distal pole of the scaphoid during radioscapholunate arthrodesis, the results of studies addressing this are summarized in (Table 3). Only one study was identified that compared distal pole scaphoid excision in RSL arthrodesis with a control group [13]. The authors reported no significant differences in patient reported outcomes, but show improvements in range of motion and union rates in the DSE group. The biomechanical study by Holleran et al 2013 demonstrated increased contact pressures in the lunocapitate and scaphotrapeziumtrapezoid joints after RSC arthrodesis in a cadaveric model. Following DSE, the authors noticed a significantly increased LC joint peak pressure despite relatively similar contact area compared to the intact wrist.

Table 3: A comparison of studies addressing distal pole scaphoid excision for RSL arthrodesis. LC = lunocapitate, STT – scaphotrapeziumtrapezoid.

Study	Fixation and Technique	Outcome Measure	Outcomes
Sraj et al 2010	3 distal radius pin plates Distal half scaphoid	Clinical: ROM, grip strength, union	-ROM: average flex/ext 85.8 degrees, radial/ulnar deviation 15 degrees -Grip strength: 81.3% of the contralateral side -2 patients midcarpal arthritis -No non union or infection

Mühldorfer-Fodor et al 2012	3 1.6mm K wires and autologous bone graft	Clinical: ROM, union, pain in RSL arthrodesis with or without DSE	-3 non union in RSL arthrodesis without DSE -No difference functional outcome and ROM. -3 deg greater radial deviation
Holleran et al 2013	Two angled locking 2.4mm distal radius plates.	Biomechanical: contact pressures LC and STT joints during simulated ROM.	-Increased contact pressure LC and STT after fusion -Increase peak pressure at LC joint after DSE

4.5. Distal Pole Scaphoid and Triquetrum Excision

The results of the studies examining the effects of distal pole scaphoid and trapezium excision during scapholunate arthrodesis are summarized in (Table 3 and Table 4). The authors in the study by Ha et al 2018 report similar patient reported outcomes between treatment groups, yet a slight increase in ulnar deviation in the triquetrum excision. The cadaveric studies in this group demonstrated significantly improved range of motion with distal scaphoid and triquetrum excision following RSL arthrodesis. The authors of McNary et al 2019 additionally report that the addition of triquetrum excision did not increase contact forces in the capitolunate joint.

Table 4: A comparison of the studies addressing triquetrum excision in an RSL arthrodesis with DSE.

Study	Fixation and Technique	Outcome Measure	Outcomes
Pervaiz et al 2009	Four 3.2mm K wires, with DSE and total triquetrum	Biomechanical: Range of motion: flex/extend and radial/ulnar deviation.	-Decreased ROM after RSL arthrodesis. -Improvement after DSE, near return to baseline after triquetrum excision.
Bain et al 2014	RSL arthrodesis with memory staples	Biomechanical: Range of motion: flex/extend and radial/ulnar deviation.	-Decreased ROM after RSL arthrodesis -Improvement after DSE, and after triquetrum excision.
Ha et al 2018	Memory staples (12), K wires, cannulated screws	Clinical: Patient outcomes, ROM, scapho-capitate and lunocapitate distance.	-15/17 satisfied at 10 years. -Increased radial deviation w/ distal triquetrum, not significant.
Leichti et al 2019	RSL arthrodesis with plate or K wires.	Clinical: Patient outcomes, ROM, grip strength.	-Irritation of FCR from K wires requiring re-operative -Midcarpal OA at 5 years, asymptomatic.
McNary et al 2019	Two 2.4 mm distal radius plates with locking screws.	Biomechanical: Capitolunate joint contact forces and area.	-Both increased with RSL fusion with DSE vs control 50% -Decreased with TE to similar to controls.
Suzuki et al 2021	Two 1.6mm K wires	Biomechanical: ROM with dart throwing	-Decreased with RSL arthrodesis 46%, improved with DSE 50%, and 62% with TE. -Increased dorsal translation after DSE and TE

4.6. Other Articles

The article by Shin et al 2007 described a technique of RSL arthrodesis using a dorsal approach and use of two angled 2.4-mm distal radius plates with iliac crest bone graft. The authors reported using cancellous bone chips if poor bone quality was noted. DSE was not routinely performed. All together the authors included 5 patients in the study and achieved successful results with no cases of non union, delayed union or infections. Lastly a recent study [2] was included in the review, in which the authors perform a systematic review specifically addressing clinical outcomes of RSL and RL arthrodesis. All together 2252 articles were reviewed in which 13 met inclusion criteria, resulting in a total of 274 patients. The authors report similar pain scores, however those that underwent RL arthrodesis had statistically significant increases in grip strength, yet decreased ROM. The nonunion rate for RSL arthrodesis was reported to be15% versus 2% for RL, whereas the rate of progression to total wrist arthrodesis for RSL and RL was 4% and 0%, respectively. The authors concluded that RSL produced better wrist ROM within functional demands, while RL arthrodesis produced low rates of both non union and progression to TWA.

5. Discussion

This comprehensive review included a total of 412 patients and 76 cadaveric specimens amongst the included studies that sought to address outcomes of techniques in RSL arthrodesis. Despite the

number of studies in this review, few RSL arthrodesis are performed every year thus making it difficult to employ a study with a large sample size. Amongst the clinical studies, that of Mühldorfer-Fodor et al 2012 included the greatest number of patients. However only 35 patients of the initial 61 had sufficient follow up. Additionally pre-operative range of motion data were not available, and there was no randomization due to the retrospective nature of the study.

The studies that sought to examine the outcomes of various fixation constructs for RSL arthrodesis all demonstrate a variety of constructs all summarized in (Table 2). The biomechanical studies demonstrate no significant difference in load to failure when a peek-optima circular plate was compared to a stainless steel oblique 3.5mm T-plate [8], however use of a headless compression screw generated increased distraction across the RSL articulation [11]. However the authors point out that this difference is likely not clinically significant, and post operative immobilization may mitigate risk while decreasing potential for tendon irritation long term. The use of headless compression screws has been shown to be successful in other types of arthrodesis such as 4 corner fusion [24] and with no difference in arthrodesis site distraction in ankle arthrodesis [25]. The clinical studies reported no incidence of non union when distal radius Pi plate was compared to a headless compression screw [9,10], however both studies employed use of bone graft while that of Galvis et al 2013 did not employ DSE. A clinical study to directly compare outcomes of RSL arthrodesis constructs, which controlled for use of bone graft and DSE and TE would shed light on this issue.

With regards to the debate about including distal pole scaphoid excision, both clinical studies in this review [12,13] conclude that excision of the distal pole of the scaphoid improves range of motion and union rates following RSL arthrodesis. These findings support the idea that resection of the distal scaphoid decreases the stress on the RSL arthrodesis site through decreasing the lever arm of an intact scaphoid and transmitting less stress along STT joint caused by an intact distal carpal row to a fused proximal row [12, 21]. Despite its advantages, it is unclear as to whether this increase in range of motion, particularly radial deviation would result in noticeable clinical outcomes. Additionally, DSE can increased contact pressures along the lunocapitate joint, which may increase forces at other midcarpal joints [14]. However there is evidence suggesting that secondary midcarpal degenerative joint disease primarily occurs in the first two years after limited wrist fusion and does not significantly progress further beyond this [22,23]. Thus in appropriately selected patients, there is sufficient data to support excision of the distal scaphoid can improve range of motion and union rates, although this may not prevent midcarpal arthrosis.

This then leads to the question about whether to excise the triquetrum during an RSL arthrodesis. The two clinical studies in this review demonstrate inconclusive results [17, 18]. Although both studies report successful union rates, the paper by Leichti et al 2019 was only a technique paper without a control group which tested only one method of fixation. Although there were no significant differences in clinical outcomes amongst the groups in Ha et al 2018, study was done retrospectively and the patients were not randomized. Additionally a variety of fixation methods were used in each group, which may have been a confounding variable. Unfortunately given the relatively few instances of this procedure being performed, it is difficult to obtain a large sample size to account for all these variables. Meanwhile more promising results were shown in the biomechanical studies reviewed, which all demonstrate significant improvement in range of motion after triquetrum excision [15,16,19,20] and decreased capitolunate contact forces. The advantage of these studies are that they were able to control for the type of fixation used. Thus although successful in biomechanical models, there yet needs to be a larger clinical study comparing outcomes of triquetrum excision.

6. Conclusion

Overall there appears to be significant variability between the various fixation constructs used to perform an RSL arthrodesis, with no clear superiority of a particular construct. If prior hardware is present, the use of a volar approach can be used to simultaneously extract hardware and perform arthrodesis without compromising the ability to achieve a successful result. Although headless compression screws demonstrated a greater distraction across the arthrodesis site, this risk can be mitigated with post operative immobilization while employing the benefits of decreased hardware prominence and tendon irritation. There is sufficient evidence to support DSE in order to improve union rates and range of motion. Although biomechanical studies demonstrate improved range of motion and decreased contact pressures to decrease incidence of midcarpal arthritis, further clinical studies are needed to support these benefits.

7. Statements

7.1. Conflicts of Interest Statement

The authors declare that they have no conflicts of interest.

7.2. Ethical Statement

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

7.3. Statement of Funding

No funds were received in support of this work. No relevant financial activities were done by any of the authors outside the submitted work.

7.4. Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects

7.5. Statement of Informed Consent

No patient informed consent was required for completion of this study.

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