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Research Article

Clinical and radiological results of early pin removal in pediatric radial neck fractures treated with stepwise percutaneous leverage technique

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ABSTRACT

Objective: The aim of this study was to compare radiological and clinical results between early (≤3 weeks) and late (>3 weeks) removal of pins in patients treated with the stepwise percutaneous leverage technique for radial neck fractures.

Methods: 37 patients (aged 3-15) who underwent fixation with stepwise percutaneous leverage technique for Judet class III and class IV radial neck fractures between 2003 and 2019 were included in this retrospective study. Patients were divided into two groups according to the time of pin removal; 19 had early pin removal (≤3 weeks) and 18 had late pin removal (>3 weeks). The patients' radiological results were graded using the Metaizeau classification and their clinical results were evaluated by measuring their range of motion (ROM) and Mayo elbow performance scores (MEPS) at postoperative follow-ups. Statistical tests, including the Mann-Whitney *U* and Chi-square tests, were performed to compare the demographic factors and outcomes.

Results: The mean time of removal of pins for all patients was 21 (10-43) days. The mean time for early and late removal was 15.1 (10-21) and 27.6 (22-43) days, respectively. There was no statistically significant difference between groups radiologically according to the Metaizeau classification ($P = .723$). Furthermore, no statistically significant difference was found in the ROM (extension/flexion: $P = .620$, pronation/supination: $P = .578$) or MEPS ($P = .695$) between groups.

Conclusion: This study has shown us that early removal of pins in patients with pediatric radial neck fractures treated with stepwise percutaneous leverage technique demonstrated good radiological and clinical results comparable to late pin removal.

Level of Evidince: Level IV, Therapeutic Study

Introduction

Most pediatric radial neck fractures with angulation more than 30˚ (Judet types III, IV) require surgical treatment.[1-3] If possible, minimal-invasive methods should be used to reduce and fix the fracture with intramedullary or percutaneous pinning.[4,5] Percutaneous pinning is widely used, not only in radial neck fractures but for other pediatric fractures as well because of the ease of surgery and pin removal.[6-8] Relatively fast fracture healing in the pediatric population is another major reason this technique, in which the pins are easily removed after a short period of pin fixation, is preferred. Stepwise percutaneous technique is one such method, and we have reported that good results can be obtained while reducing the risk of posterior interosseous nerve injury in pediatric radial neck fracture.[9]

On the other hand, percutaneous pinning is more likely to cause infection and skin irritation because the pin tip must be exposed to the outside or buried close to the skin.[10,11] Therefore, it is desirable to reduce the pin retention period while ensuring the stability of the fracture site. Although some studies suggested 3 weeks as appropriate pin retention period,[12,13] there is no clear consensus on how long pins should be maintained; it often depends on the surgeon's subjective experience.

In this study, the pin of a pediatric radial neck fracture was removed after an undefined time, considering the radiographic alignment and the patient's symptoms. Based on the 3-week pin retention period suggested in the previous studies,[12,13] patients were divided into the early removal group and late removal group. The 2 groups may have been assigned somewhat randomly, as there were no consistent criteria for determining when to remove pins. It was hypothesized that early removal did not affect the outcome. To confirm this, we compared the outcomes of the 2 groups and analyzed other factors that could affect the outcome.

Materials and Methods

Between 2003 and 2019, patients with radial neck fracture who were operated on by the same surgeon at a single institution were included in this study. The criteria for inclusion in the study were defined as patients (1) who were 3 to 16 years of age; (2) with ossification of the radial head on simple radiographs; (3) with a severely angulated radial neck fracture classified as type III or IV (Judet classification); and (4) treated by percutaneous pin fixation. A total of 37 patients were included in this study.

The patients were divided into 2 groups according to the amount of time their pin was maintained. The

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Table 1. Demographic factors of patients and injury characteristics

Patients	Group	Duration of pinning (days)	Sex	Age	Injury in dominant side	Interval from injury to surgery (days)	Direction of displacement	Judet Type	Translation (≥100%)	Associated injuries
1	Late	25	F	11	No	2	Lateral	III	No	No
2	Late	28	M	10	No	2	Lateral	III	No	No
3	Late	23	F	6	No	1	Lateral	III	No	No
4	Late	43	M	9	No	1	Lateral	III	No	No
5	Late	31	F	10	Yes	2	Lateral	III	No	No
6	Late	28	F	5	Yes	1	Lateral	III	No	No
7	Early	20	F	9	No	1	Lateral	IVb	No	No
8	Late	30	F	5	Yes	1	Lateral	III	No	Olecranon fracture
9	Late	27	F	15	Yes	3	Lateral	III	No	No
10	Late	27	F	9	No	2	Lateral	IVa	No	No
11	Late	24	F	10	Yes	5	Posterior	III	No	No
12	Late	31	F	11	No	0	Lateral	IVb	No	No
13	Early	19	M	9	Yes	1	Lateral	IVa	No	No
14	Early	13	M	7	No	1	Lateral	III	No	Olecranon fracture
15	Late	36	M	11	Yes	1	Lateral	III	No	No
16	Late	23	M	9	No	2	Lateral	III	No	Olecranon fracture
17	Late	22	F	8	Yes	0	Lateral	III	No	No
18	Late	24	F	6	No	0	Lateral	III	No	No
19	Early	15	F	11	No	0	Lateral	III	No	No
20	Early	10	F	3	Yes	0	Lateral	III	No	No
21	Early	18	F	5	Yes	1	Lateral	IVb	No	Olecranon fracture
22	Late	26	M	8	Yes	0	Lateral	IVb	No	No
23	Early	18	F	10	No	1	Lateral	III	No	Olecranon fracture
24	Late	23	F	11	Yes	1	Lateral	IVb	No	Olecranon fracture
25	Early	21	F	10	No	4	Lateral	III	No	No
26	Early	21	M	13	No	1	Lateral	III	No	No
27	Early	13	F	7	Yes	2	Lateral	III	No	No
28	Late	25	M	8	No	0	Lateral	III	No	Olecranon fracture
29	Early	11	F	6	No	0	Lateral	IVb	Yes	No
30	Early	10	M	10	Yes	1	Lateral	IVb	No	No
31	Early	12	M	11	Yes	1	Lateral	III	No	No
32	Early	18	M	11	No	1	Lateral	III	Yes	Olecranon fracture
33	Early	10	F	6	Yes	1	Lateral	IVb	No	No
34	Early	18	M	10	Yes	4	Lateral	III	No	No
35	Early	11	F	5	No	2	Lateral	IVa	No	No
36	Early	11	F	3	No	3	Lateral	III	No	No
37	Early	17	M	8	Yes	1	Lateral	III	No	Olecranon fracture

3-week pin retention period suggested in the previous studies was defined as the cut-off value.[12,13] Nineteen patients who had been pinned for a period of 3 weeks or less were assigned to the early pin removal group. Eighteen patients who were pinned for more than 3 weeks were assigned to the late pin removal group. Table 1 summarizes the demographics and other factors related to fracture and surgery in all patients.

Fundamentally, the technique for an operation on a radial neck fracture is based on the stepwise percutaneous leverage technique.[9] In this method, a 2.0-mm Steinmann pin (S-pin) is inserted at the fracture site and the fracture is reduced by leverage technique. The S-pin is then removed to release the soft tissue kinked in the process of fracture reduction and minimize the potential for posterior interosseous nerve damage. During the pin removal, the fracture site is supported by the thumb and a second S-pin is inserted to secure the fracture site. The pin is exposed to the outside of the skin and bent for easy removal (Figure 1).

HIGHLIGHTS

- Percutaneous pinning is commonly used in treatment of pediatric radial neck fractures. There is no clear consensus on how long pins should be maintained and this study aimed to investigate the effect of early and late pin removal on pediatric radial neck fractures treated with stepwise percutaneous leverage technique.
- The results showed no statistically significant difference in extension/flexion, pronation/supination or Mayo Elbow Performance Score between groups. Complication rate was also not significantly different between groups.
- The results from this study suggest that removal of the pin within 3 weeks after stepwise leverage percutaneous pinning in pediatric radial neck fractures yields comparable outcomes to late removal. However, for fractures with initial proximal fragment displacement of 100% or more than the diameter of the radial neck.

The timing of pin removal was determined by the subjective judgment of the surgeon (JHC) in consideration of the alignment of radial neck fracture on the follow-up radiograph and the patient's symptoms. A long arm splint or cast was applied to the injured arm for 3 weeks after surgery regardless of the timing of pin removal. Whether to apply a splint or cast to a patient was determined by patient compliance and parental request. A splint or cast was applied with the elbow bent 90˚ and the forearm in a neutral position. If a cast was applied, a small window was opened on the side of the cast for pin site dressing. After the splint or cast was removed, range-of-motion exercise was allowed with or without a pin. Early range-of-motion exercise of elbow focused on flexion-extension exercise. Forearm rotation exercise usually began after pin removal. This is because pins inserted into the radial neck can limit rotation of the forearm

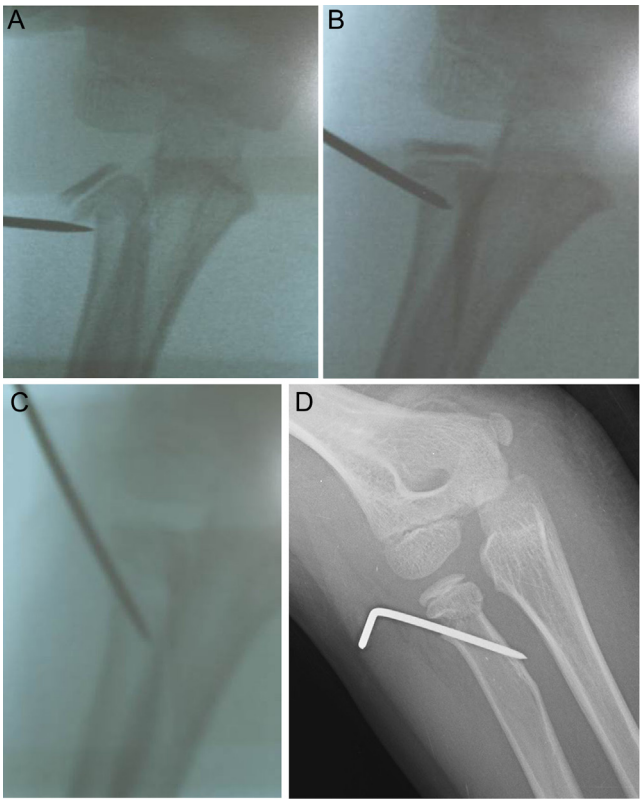

Figure 1. (a) S-pin was inserted at the fracture site and (b) the fracture was reduced by leverage technique. (c) A second S-pin was inserted to secure the fracture site. (d) Immediate postoperative radiograph showed that the pin was bent out of the skin.

and exacerbate soft tissue irritation. The first follow-up was performed between 7 and 10 days postoperatively, followed by a weekly follow-up until pin removal. Thereafter, follow-up was performed 1 week immediately after pin removal, 6 weeks, 3 months, 6 months, and 1 year after surgery. In general, 1 year was the last follow-up.

Postoperative results were evaluated after 1 year. The anteroposterior view of simple radiographs was used for measuring radiological outcomes. The radiological outcomes were graded based on the Metaizeau classification: excellent, if the fracture healed in the anatomical position; good, when the radial neck angle was less than 20˚; fair, when the angle was between 20˚ and 40˚; poor, when the angle was over 40˚. Two observers, including an experienced consultant pediatric orthopedic surgeon and a hand surgeon specialized in upper extremity trauma, independently measured the radial neck angle on the anteroposterior view of a simple radiograph. A hand surgeon re-measured all the radiographs 1 month later. Intra- and inter-observer reliability were assessed by using the intraclass correlation coefficient (ICC),[14] and the mean of the radial neck angle measured by the 2 observers was used to determine the Metaizeau classification. Radiographs were also followed 1 week after pin removal. Early reduction loss was determined by comparison with previous radiographs. The clinical outcomes were evaluated based on Mayo elbow performance score (MEPS) at the last follow-up (Table 2). The ranges of motion (ROMs; extension/flexion, supination/pronation) of the elbow were also measured with a goniometer at the last follow-up. Whether additional antibiotics (first-generation cephalosporin, methyol cephalexin lysinate) were administered was also investigated.

Several statistical tests were performed to compare the demographic factors and outcomes of the 2 groups. The Mann- Whitney U test was used for continuous variables, the chi-square test and Fisher's exact test were used for the variables composed with categories. Fisher's exact test was used when the expected frequency (the number of events in each group) was less than 5. Otherwise, a Chi-square test was used. The linear-by-linear association method was used for the variables composed with 3 or more categories. Post-hoc power analysis was performed to evaluate the validity of the sample size. $P < .05$ was considered significant. Local institutional review board approval from Ajou University Hospital was obtained for the study (AJIRB-MED-MDB-15-473).

Table 2. Mayo elbow performance score

Pain (mas 45 pt)	ROM (max 20 pt)	Stability (max 10 pt)	Function (max 25 pt)	Total (max 100 pt)
None (45 pt)	100° (20 pt)	Stable (10 pt)	Able to comb hair (5 pt)	Excellent ≥90 pt
Medium (30pt)	50-100° (15 pt)	Moderately unstable (5 pt)	Able to feed oneself (5 pt)	Good 75-89 pt
Moderate (15 pt)	< 50° (5 pt)	Grossly unstable (0 pt)	Able to put on shirt (5 pt)	Fair 60-74 pt
Severe (0 pt)			Able to put on shoes (5 pt)	Poor <60 pt
			Able to perform personal hygiene (5 pt)	

Results

The mean pin maintenance period of all patients was 21 (10-43) days. The mean pinning period of the early pin removal group was 15.1 (10-21) days, and the mean pinning period of the late pin removal group was 27.6 (22-43) days. There were no significant differences in age, sex, and dominant side injury between the two groups. There were also no significant differences in the associated injuries, the degree of initial angulation (Judet classification), the direction of the displacement, and the amount of time before surgery (Table 3). Fisher's exact test was used for some factors such as associated injury, displacement direction, and horizontal displacement greater than 100% of diameter. This is because the expected frequency (number of events) was less than five for these factors.

Table 4 summarizes the postoperative outcomes in all patients. The ICCs for the radial neck angle were 0.801 for intra-observer reliability

Table 3. Comparison of the demographics and other factors related to fracture and surgery in each group

		Early pin removal group (≤3 weeks)	Late pin removal group (>3 weeks)	*P*
Patients		19	18	
Sex	Male	8	6	.582
	Female	11	12	
Age		8.25(3-13)	9(5-15)	.461
Dominant side injury		10	10	.879
Associated injuries	Olecraonon fracture	5	4	.538
Judet classification	III	12	14	.378
	IVa	2	1	
	Ivb	5	1	
Direction of displacement	Lateral	19	17	.486
	Posterior	0	1	
Interval from injury to surgery		1.37(0-4)	1.33(0-5)	.964
Horizontal displacement (≥100%)		2	0	.486

Table 4. Radiological and clinical outcomes

Patients	Group	Range-of-motion (extension/flexion)	Range-of-motion (pronation/supination)	Metaizeau classification	MEPS*	Complications
1	Late	150	160	Excellent	Excellent	
2	Late	150	0	Fair	Good	Synostosis
3	Late	150	160	Good	Excellent	
4	Late	150	160	Excellent	Excellent	Pin site infection
5	Late	150	160	Excellent	Excellent	
6	Late	150	160	Good	Excellent	Pin site infection
7	Early	150	160	Excellent	Excellent	
8	Late	150	160	Excellent	Excellent	
9	Late	150	160	Good	Excellent	
10	Late	150	160	Excellent	Excellent	
11	Late	150	160	Excellent	Excellent	Pin site infection
12	Late	150	160	Excellent	Excellent	
13	Early	150	160	Excellent	Excellent	
14	Early	150	160	Good	Excellent	
15	Late	150	130	Good	Good	
16	Late	150	160	Excellent	Excellent	
17	Late	150	160	Excellent	Excellent	
18	Late	150	160	Excellent	Excellent	
19	Early	150	160	Excellent	Excellent	
20	Early	150	160	Good	Excellent	
21	Early	150	160	Excellent	Excellent	
22	Late	150	160	Excellent	Excellent	
23	Early	150	160	Excellent	Excellent	
24	Late	110	130	Excellent	Good	
25	Early	150	160	Good	Excellent	
26	Early	135	160	Excellent	Excellent	
27	Early	150	160	Good	Excellent	
28	Late	150	160	Good	Excellent	
29	Early	110	120	Poor	Fair	
30	Early	150	160	Excellent	Excellent	
31	Early	150	160	Excellent	Excellent	
32	Early	135	160	Fair	Good	Nonunion
33	Early	150	160	Excellent	Excellent	
34	Early	150	160	Excellent	Excellent	
35	Early	150	160	Excellent	Excellent	Pin site infection
36	Early	150	160	Excellent	Excellent	
37	Early	150	160	Excellent	Excellent	

*Mayo Elbow Performance Score

and 0.843 for inter-observer reliability, suggesting excellent reliability.[14] According to the Metaizeau classification, 13 cases were classified as excellent, 4 cases as good, 1 as fair, and 1 as poor in the early pin removal group. In the late pin removal group, 12 cases were classified as excellent, 5 cases as good, and 1 case as fair. The difference in Metaizeau classifications between the two groups was not statistically significant (P =.723). There was also no difference in the ROMs of the elbow between the 2 groups (extension/flexion: P=.620, pronation/supination: P =.578). Using the MEPS, 17 cases from the early pin removal group were evaluated as excellent, 1 case was evaluated as good, and 1 case was evaluated as fair. In the late removal group, 15 cases were excellent and 3 cases were good. There

Table 5. Comparison of the radiological and clinical outcomes of each group

		Early pin removal group (≤3 weeks)	Late pin removal group (>3 weeks)	*P*
Complications	Nonunion	1	0	
	Synostosis	0	1	
	Pin site infection	1	3	.340
Arc of motion	Extension/flexion	144.2(110-150)	130(110-150)	.620
	Supination/pronation	156.7(120-160)	145(0-160)	.578
Metaizeau classification	Excellent	13	12	.723
	Good	4	5	
	Fair	1	1	
	Poor	1	0	
†MEPS	Excellent	17	15	.695
	Good	1	3	
	Fair	1	0	
	Poor	0	0	

†Mayo Elbow Performance Score

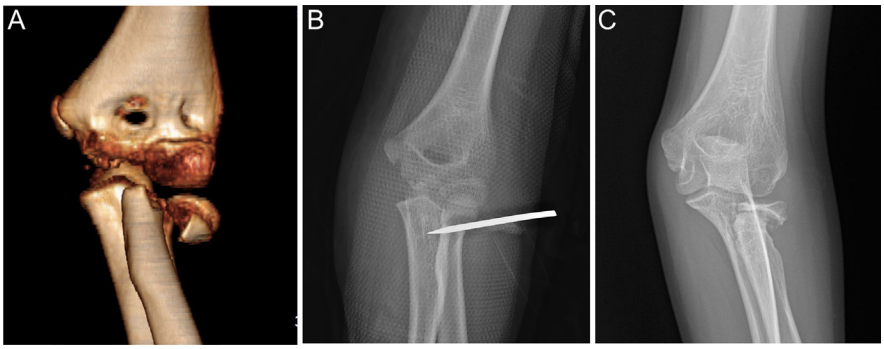

Figure 2. (a) Initial three-dimensional CT of an 11-year-old boy with radial neck fracture showed that the fractures had been displaced horizontally by more than 100% of the diameter of the radial neck. (b) The postoperative alignment of the radial head fracture was good enough to remove the pin early, (c) but, eventually resulted in a nonunion.

was no significant difference in the MEPS between the 2 groups (P =.695) (Table 5). In the post-hoc power analysis to determine the difference in MEPS between the 2 groups of this sample size, the power was 0.83.

All patients in the late removal group required pin care without additional immobilization because immobilization period was 3 weeks after surgery. The duration of pin care without immobilization varied depending on when the pin was removed and ranged from 1 to 22 days.

Prophylactic intravenous antibiotics were used only on the day of surgery in all patients. In early pin removal group, 1 case of additional oral antibiotic was used. In late pin removal group, 3 cases of additional oral antibiotic were used for pin site infection. The infection was judged by clinical symptoms such as redness or discharge of the pin site.

There were 6 complications such as nonunion, synostosis, or superficial skin infection. One case of nonunion belonged to the early pin removal group (Figure 2) and one case of synostosis belonged to the late pin removal group. Pin site infection occurred in 4 cases, that is 1 case in the early pin removal group and 3 cases in the late pin removal group. Because they were all superficial skin infections, they were treated without any further intervention after oral antibiotics and pin removal.

Discussion

The aim of this study was to determine whether early pin removal is appropriate in children with radial neck fractures treated by stepwise leverage technique. We divided the participants into 2 groups based on the duration pinning (within or > 3 weeks) and compared the results. There was no significant difference in the characteristics of the fracture, such as the direction of initial displacement, the degree of angulation, and the existence of associated fractures between the 2 groups. The demographic factors such as age and sex were also not significantly different between the two groups. Since there was no significant difference in outcomes between the 2 groups, it was judged that the duration of pinning had little influence on the outcomes.

Despite the short pin maintenance period of < 3 weeks, good outcomes were achieved because there was almost no loss of reduction after pin removal. The anatomical characteristics of a pediatric radial head might have contributed to the maintenance of reduction. First, a buttressing effect can be obtained by articulation of the radial head with the capitellum proximally and with the radial notch of the ulna medially. Second, the force to cause displacement of the radial head is weak because there is no musculotendinous structure attached to the radial head except the joint capsule and annular ligament. Third, the periosteum on the lateral side of the radial neck is likely to be intact because of the nature of childhood fractures.

Percutaneous pinning is an easy and common method to stabilize fractures, but the incidence of complications is reported as up to 44%.[15] Complications include local complications such as pin migration, pin breakage, pin track infection, or nerve injury and systemic complications such as toxic shock syndrome.[15-18] Among them, a pin tract infection is one of the most common complications and the incidence was reported as 0.5-100%.[10,17,19,20] The longer the pin fixation period, the greater the possibility of a pin tract infection;[16,21] therefore, it is better to remove the pin as early as possible if the fracture site is stabilized. In view of dressing care and additional oral antibiotics usage, early pin removal is more beneficial. Early pin removal group shows tendency of minimal scar formation and less soft tissue dimpling or hypertrophy. After surgery, range-of-motion exercise should be started as soon as possible to prevent stiffness, but the elbow motion with a percutaneous pin can irritate the soft tissue and affect the infection rate. Therefore, early pin removal is also required for early exercise.

Conventional percutaneous technique that reduce and fix fracture site with a single pin can damage surrounding soft tissue, including posterior interosseous nerve.[22-26] If the soft tissue manipulated during the reduction process is not sufficiently relaxed and is kept under pressure by pin, a wound may develop and cause an infection. In addition, pin inserted into soft tissue that is not relaxed may be subjected to continuous pressure by soft tissue restoring force, which lead to instability of fracture site. We think the stepwise leverage technique could reduce these complications.

In this study, one case of nonunion occurred in the early pin removal group. In the initial elbow radiographs of this case, the fracture had been displaced horizontally by more than 100% of the diameter of the radial neck. The postoperative alignment of the radial neck fracture was good enough to remove the pin early but eventually resulted in a nonunion. It was expected to be unstable due to the displacements so severe that it caused periosteal breakage or annular ligament rupture. Therefore, in such a case, it is recommended to retain the pin for three weeks or more. The pin must be held for a long time until radiographic healing such as callus formation occurs.

There were several limitations in this study. First, a randomized controlled trial could not be performed due to its retrospective design. However, there were no significant differences in the several factors that could affect the outcome of the two groups; therefore, the probability of selection bias was expected to be rather low. Second, the sample size was rather small. However, the post-hoc power analysis showed 0.83 of power, which means that the sample size is not insufficient. The number of subjects required to have a power of 0.8 was 34 patients (17 patients were required in each group).

In conclusion, removal of the pin within 3 weeks after stepwise leverage percutaneous pinning in pediatric radial neck fractures showed equivalent outcomes as in the case of late removal. However, in cases with very unstable fractures, in which the proximal fragment is initially displaced by 100% or more of the diameter of the radial neck, a sufficient pinning period is necessary.

Ethics Committee Approval: Institutional review board approval was received from the Ajou University Hospital (Approval No: AJIR B-MED-MDB-15-473).

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Author Contributions: Concept – T.H.K., W.-S.C; Design – J.-H.C., W.-S.C; Supervision – K.-J.H., D.-H.L.; Materials – J.-H.C.; Data Collection and/or Processing – J.M.L., W.-S.C.; Analysis and/or Interpretation – J.-H.C., W.-S.C.; Literature Review – J.M.L.; Writing – T.H.K.; W.-S.C.; Critical Review – J.-H.C., W.-S.C.

Declaration of Interests: The authors have no conflicts of interest to declare.

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