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Original article

Analysis of loss of reduction as risk factor for additional secondary displacement in children with displaced distal radius fractures treated conservatively

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ABSTRACT

Background: The distal radius is the most common site of fracture in childhood, and the conservative treatment is widely used. The major casting complication is the loss of reduction and the redisplacement of the fracture.
Hypothesis: According to the risk factors, close reduction and casting is the gold standard as first option of treatment of distal radius fractures (DRFs).
Methods: According to 1-week X-ray, 101 pediatric conservatively treated for DRFs patients were divided into 2 groups: Group A (non-displaced) and Group B (secondary displacement). The sample underwent radiographic follow-ups at the emergency room, 1, 2 and 6 weeks after-treatment. The radiographic assessment included initial translation grade, following Mani criteria; initial reduction quality; if there were fractures of both bones; and the cast (CsI), padding (PI), canterbury (CaI), gap (GI), and three-point (3PI) indices.
Results: Group A had 16 Mani grade III–IV initial translations; 37 anatomic reductions (47.4%); 48.7% fractures of both bones; and index means of CsI: 0.8, PI: 0.2, CaI: 1.0, GI: 0.16, and 3PI: 0.9. Group B had 13 Mani grade III–IV initial translations; 3 anatomic reductions (13.0%); 65.2% fractures of both bone; and index means of CsI: 0.9, PI: 0.3, CaI: 1.2, GI: 0.18, and 3PI: 1.0. The overall odds ratio indices were CsI: 4.7, CaI: 4.8, GI: 2.4, PI: 3.2, and 3PI: 3.6.
Conclusion: The study hypothesis was partially confirmed: Casting is a simple, safe, effective, and inexpensive treatment DRFs in childhood. In our opinion, after a good-quality reduction, conservative treatment should be the gold standard for non-displaced and <50% of displaced fractures. CsI, PI, and CaI calculations are recommended as secondary displacement predictors.
Level of evidence: III, retrospective case control study.

1. Introduction

In children, the most common fracture location is the distal radius, which accounts for 25–43% of all fractures [1,2]. Although most patients are treated by closed reduction and casting (CRC), several treatment options have been reported for the management of distal radius fractures (DRFs) in skeletally immature patients [3,4].

Loss of reduction (LOR) following CRC has been reported as the most common complication in children with displaced DRFs treated conservatively [5], with a rate of secondary displacement (SD) ranging 21–47% [5,6]. The risk factors for SD following CRC can be classified as "fracture-related" (FR) or "surgeon-related" (SR) [7]. Displacement at the fracture siteand residual angulation are the main FR factors [8–10]. SR factors can be radiographically assessed by measuring the following indices: cast (CsI), the padding (PI), the canterbury (CaI), the gap (GI), and the three-point (3PI) [11,12]. Although several authors have attempted to evaluate the optimal predictor of SD in children with conservatively treated DRFs, the best predictor has not yet been identified [11,12].

The aim of the study is to:

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Table 1
Groups' demographics.

N	M	F	Sex ratio	Mean age	Side		Ulna-associated		Initial translation (Grade)				Initial reduction		
					Right	Left	Yes	No	1	2	3	4	Anatomic	Good	Fair
Patients															
101	68	33	2.06	11.5 ± 1.7	63	38	53	48	48	24	17	12	40	43	18
Group A															
78	52	26	2.00	11.8 ± 1.2	48	29	38	40	43	19	10	6	37	35	6
Group B															
23	16	7	2.29	11.1 ± 2.1	14	9	15	8	5	5	7	6	3	8	12
	>0.05			>0.05	0.90		0.03		0.01				<0.00001		

M: male; F: female.

- demonstrate close reduction and casting is the gold standard as first option of treatment of distal radius fractures (DRFs);
- assess the relationship between SD, FR and SR factors;
- identify the best predictor of SD.

2. Materials and methods

2.1. Patients

A retrospective medical record review (2012–2017) was performed of under-16-years-patients who sustained CRC for DRFs. The inclusion criteria were as follows:

- confirmed diagnosis of displaced DRF (>10° angulation on lateral radiographs; >20° angulation on AP radiographs; <50% apposition on AP or lateral radiographs);
- patient age under 16 years;
- treatment at the emergency department as per "treatment protocol" described below and;
- complete radiographic data.

One hundred and one patients – 68 (67.3%) male and 33 (32.7%) female – were eligible and selected for the study. According to following SD criteria one-week X-ray:

- >10° angulation on the AP radiograph;
- >20° angulation on the lateral radiograph;
- <50% apposition on either radiograph, or;
- >15° change on the lateral radiograph at the 1-week assessment, the cohort were divided into two groups: "non-displaced DRF" (Group A) and "displaced DRF" (secondary displacement; Group B).

Seventy-eight patients (52 boys) with a mean age of 11.8 ± 1.2 years (range 9.9–13.5) were in Group A; and 23 patients (16 boys) with a mean age of 11.1 ± 2.1 years (range 8.7–12.9) were in Group B (Table 1). In Group B, 12 patients required secondary surgical treatment (closed reduction and percutaneous pinning; CRPP), while the remaining 11 required additional closed reduction and recasting. Group A and Group B did not differ significantly in their demographics ($p > 0.05$),

2.2. Treatment protocol

Prior to CRC, patients were administered equimolecular N_2O_2 for at least 15 consecutive minutes. Under fluoroscopy control, a maximum of two attempts was allowed for a proper reduction before surgery was performed. Post-operatively, all patients were immobilized in a long arm cast for 6 weeks, with the elbow at 90–100° of flexion and the forearm in a neutral position.

2.3. Risk factor evaluation

The injured sides were imaged with antero-posterior (AP) and lateral radiographs of the forearm to evaluate the location of the fracture and the direction and amount of displacement, and to assess consolidation. Radiographs were taken 1, 2, and 6 weeks after reduction, then every six months.

Translation was graded I to IV according to Mani et al. Grade I fractures have no translation, grade II have translation <50%, grade III have translation >50%, and grade IV are completely displaced [13].

The quality of the initial reduction was graded according to Alemdaroglu et al. as:

- "anatomic reduction" without any residual translation nor angulation;
- "good reduction" with <10° of residual dorsal angulation or 2 mm of residual translation and;
- "fair reduction" with 10° to 20° residual angulation or residual translation of 2–5 mm [14].

Moreover, following reduction and casting, the CsI, PI, CaI, GI, and 3PI were measured in all patients (Fig. 1).

The CsI is calculated at the fracture site as the ratio between the inner diameter of the cast on lateral radiographs and the inner diameter of the cast on AP radiographs; if the ratio exceeds 0.7, the risk of SD is higher [15].

PI is the ratio between the inner cast to bone/skin distance on lateral radiographs, and the maximum interosseous distance on AP radiographs; if the ratio is over 0.3, the risk of SD is higher [16].

The CaI is the sum of the CsI and PI; if the result is more than 1.1, the risk of SD is higher [16].

The GI assesses the space between plaster and skin; it is the ratio between the inner plaster diameter on AP radiographs and lateral radiographs (measurements performed at the fracture site); if the ratio exceeds 0.15, the risk of secondary displacement is higher [17].

The 3PI takes into account the gap at the fracture site and the gap proximal and distal to the fracture; for values over 0.8 the risk of secondary displacement is higher [14].

2.4. Statistical analysis

Continuous data are presented as means and standard deviations. The *t*-test was used to compare CsI, PI, CaI, GI, and 3PI means between the two groups. The χ^2-test was used to verify the homogeneity of the two groups based on age, gender, and laterality and to compare the cutoff value of each index. The odds ratio (OR) was used to quantify the risk factor; the following parameters were calculated to characterize the quality of each index: sensitivity, specificity, positive likelihood ratio (PLHR), negative likelihood ratio (NLHR), positive predictive value (PPV), negative predictive

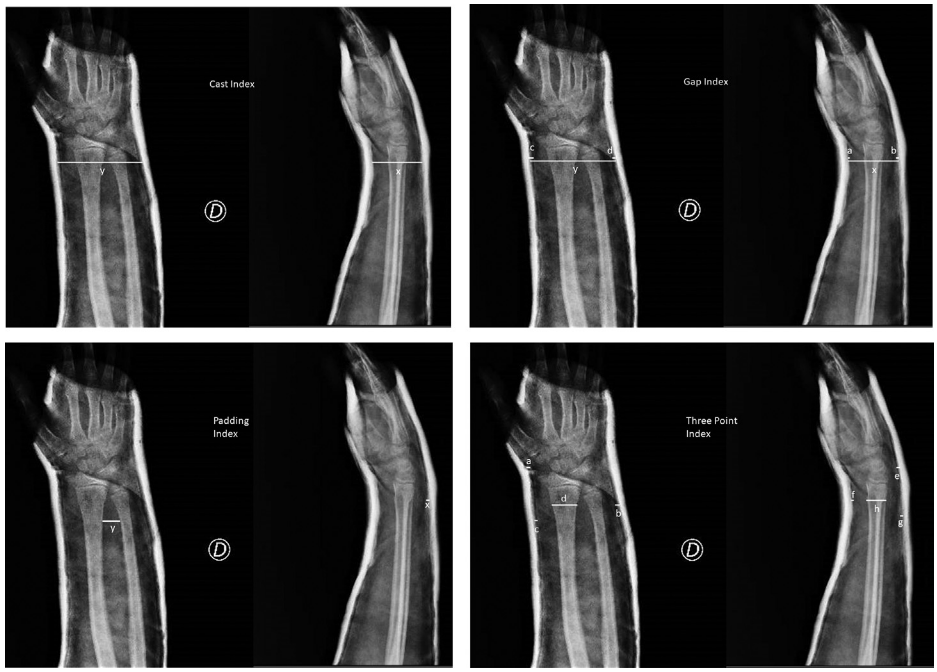

Fig. 1. Example of cast (CsI), padding (PI), gap (GI), and the three-point (3PI) indexes calculation.

value (NPV), and accuracy. The selected threshold for statistical significance was $p < 0.05$. All statistical analyses were performed using the 2016 GraphPad Software.

3. Results

3.1. FR and SR factors analysis

Group A and Group B differed significantly for the initial amount of translation, quality of initial reduction, and presence of ulna-associated fracture ($p < 0.05$). Group B (56.5%) had significantly worse initial translation compared to Group A (20.5%; $p < 0.01$), with an OR of 5.0 (95% confidence interval [CI]: 1.–13.6) (Table 1).

The quality of the initial reduction was significantly better in Group A than Group B ($p < 0.0001$), with an OR of 13.1 (95% CI: 4.1–42.1). Facture in both forearm bones had an OR of 2.0 (95% CI: 0.7–5.2) and in Group B the incidence significantly higher ($p = 0.03$) (Table 1). Significant differences were found between the indexes ($p < 0.05$) cutoff except for the GI ($p = 0.07$). CsI had the highest OR (OR: 4.8; 95% CI: 4.1–42.1), whilst the GI had the lowest (OR: 2.4; 95% CI: 4.1–42.1) (Table 2). Comparing the CsI, PI, CaI, and 3PI means, statistically significant differences were found between the two groups. Groups A and B's GI means were found to be similar ($p = 0.32$) (Table 2).

3.2. SD predictors analysis

The CsI had the highest sensitivity (78.3%) and NPV (89.8%). However, the PI had the highest PPV (42.1%) and accuracy (74.3%); the 3PI had the highest specificity (87.8%) and PLHR (2.7); and the GI had the highest NLHR (0.82) (Table 3).

Table 4 reports the results of the association between two radiographic indexes. CsI + CaI had the highest sensitivity (71.4%) and NPV (88.5). The highest specificity (86.6%) and PLHR (2.49) were found in PI + 3PI. CaI + 3PI showed the highest NLHR (1.43). GI + 3PI had the highest NPV (69.6%), while PI + CaI showed the highest accuracy (72.3%).

The association between three radiographic indexes was reported in Table 5. CsI + PI + CaI showed the highest sensitivity (59.42%), NPV (85.6%), and accuracy (68.6%). PI + GI + 3PI showed the highest specificity (86.0%), PLHR (2.31), and PPV (61.5%). CI + GI + 3PI had the highest NLHR (0.82).

4. Discussion

This report found that displaced DRFs treated conservatively are at higher risk of SD in cases of poor initial translation, presence of associated ulna fracture, and insufficient quality of closed reduction. Moreover, the quality of the cast, excessive and un-uniform padding, and the absence of a proper "three-point fixation" molding are other factors affecting the outcome and potentially leading to SD [18]. Overall, 11.9% of children required secondary surgical treatment. CaI appears to be the SD best predictor in children. Interestingly, the association of 2 or more indexes does not improve the predictive power of radiological assessment.

4.1. FR and SR factors analysis

LOR is a relatively frequent complication of pediatric forearm fractures treated conservatively [18]. Interestingly, the SD risk is 13 times higher in Mani et al. grade III and IV fractures [13]. In our series, only 18% of cases had a fair reduction [14]. Moreover, patients with fair initial reduction have a SD risk 14 times higher than other patients [14]. In particular, 87% of Group B fractures had quality of reduction judged as fair, thus confirming the importance of the quality of the reduction to prevent SD [5,14,15]. We also found that children with DRFs with associated ulna fractures have a higher risk of SD (OR = 2; 95% C.I.: 0.75–5.2); 65% and 48% of fractures involved both forearm bones in Group B and Group A, respectively ($p = 0.03$).

4.2. SD predictors analysis

The quality of casting and padding is also mandatory [5,6]. LOR after poor casting occurs in 12–34% of cases. The essential elements for good plaster cast placement are proper molding, thin uniform padding, and three-point-fixation [19].

Table 2
Radiological assessment.

	Group A	Group B	*p*-values	Odds ratio
Cast Index	0.8 ± 0.06	0.9 ± 0.1	<0.0001	4.7 (95% CI: 1.6–13.8)
	44/78 (56.4%)	5/23 (21.7%)	0.003	
Padding Index	0.2 ± 0.09	0.3 ± 0.13	<0.0001	3.2 (95% CI: 1.1–9.5)
	67/78 (85.9%)	15/23 (65.2%)	0.02	
Canterbury Index	1.0 ± 0.15	1.2 ± 0.26	<0.0001	4.8 (95% CI: 1.8–12.8)
	56/78 (71.8%)	8/23 (34.8%)	0.001	
Gap Index	0.16 ± 0.08	0.18 ± 0.12	0.32	2.4 (95% CI: 0.9–6.4)
	44/78 (56.4%)	8/23 (34.8%)	0.07	
Three-Point Index	0.9 ± 0.16	1.0 ± 0.23	0.02	3.6 (95% CI: 1.3–10.1)
	43/78 (55.1%)	6/23 (26.1%)	0.01	

Table 3
Regression analysis of the radiological indexes.

	Cast Index	Padding Index	Canterbury Index	Gap Index	Three-Point Index
Sensitivity (95% CI)	**78.3%** ((56.3–92.5%)	**34.8%** ((16.4–57.3%)	**65.2%** ((42.7–83.6%)	**65.2%** ((42.7–83.6%)	**32.7%** ((20.3–47.1%)
Specificity (95% CI)	**56.4%** ((44.7–67.6%)	**85.9%** ((76.2–92.7%)	**71.8%** ((60.5–81.4%)	**55.1%** ((43.4–66.4%)	**87.8%** ((75.2–95.4%)
PLHR (95% CI)	**1.8** ((95% 1.3–2.5)	**2.5** ((1.1–5.4)	**2.3** ((1.5–3.7)	**2.0** ((0.9–4.3)	**2.7** ((1.1–6.2)
NLHR (95% CI)	**0.4** ((0.2–0.9)	**0.8** ((0.6–1.0)	**0.5** ((0.3–0.9)	**0.8** ((0.7–1.0)	**0.8** ((0.6–0.9)
PPV (95% CI)	**34.6%** ((27.5–42.4%)	**42.1%** ((24.9–1.4%)	**40.5%** ((30.0–52.0%)	**30.0%** ((95% C.I.: 22.5–38.7%)	**73.9%** ((54.9–86.8%)
NPV (95% CI)	**89.8%** ((79.8–95.1%)	**81.7%** ((76.6–85.9%)	**87.5%** ((79.7–92.6%)	**84.6%** ((75.2–90.9%)	**55.1%** ((49.7–60.4%)
Accuracy (95% CI)	**61.4%** ((51.2–70.9%)	**74.3%** ((64.6–82.4%)	**70.3%** ((60.4–79.0%)	**58.4%** ((48.2–68.1%)	**59.4%** ((49.2–69.1%)

PLHR: positive likelihood ratio; NLHR: negative likelihood ratio; PPV: positive predictive value; NPV: negative predictive value.

Table 4
Regression analysis of the association of 2 radiological indexes.

	Sensitivity (95% CI)	Specificity (95% CI)	PLHR (95% CI)	NLHR (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)
CI + PI	**56.5%** ((41.1–71.1%)	**71.1%** ((63.4–78.1%)	**2.0** ((1.4–2.8)	**0.6** ((0.4–0.9)	**36.6%** ((28.9–45.1%)	**84.7%** ((79.7–88.7%)	**67.8%** ((60.9–74.2%)
CI + CaI	**71.7%** ((56.5–84.0%)	**64.1%** ((56.0–71.6%)	**2.0** ((1.5–2.6)	**0.4** ((0.3–0.7)	**37.1%** ((30.9–43.7%)	**88.5%** ((82.7–92.5%)	**67.8%** ((58.9–72.3%)
CI + GI	**45.8%** ((34.0–58.0%)	**67.7%** ((58.9–75.6%)	**1.4** ((1.0–2.0)	**0.8** ((0.6–1.0)	**44.0%** ((35.6–52.8%)	**69.3%** ((63.9–74.2%)	**59.9%** ((52.8–66.7%)
CI + 3PI	**46.7%** ((35.1–58.6%)	**68.5%** ((59.7–76.4%)	**1.5** ((1.0–2.1)	**0.8** ((0.6–1.0)	**46.7%** ((38.1–55.5%)	**68.5%** ((63.1–73.5%)	**60.4%** ((53.3–67.2%)
PI + CaI	**50.0%** ((34.9–65.1%)	**42.1%** ((24.9–61.4%)	**2.4** ((1.6–3.6)	**0.6** ((0.5–0.9)	**41.1%** ((31.4–54.4%)	**84.6%** ((79.8–87.8%)	**72.3%** ((65.6–78.3%)
PI + GI	**31.9%** ((21.4–44.0%)	**85.4%** ((78.1–91.0%)	**2.2** ((1.3–3.7)	**0.8** ((0.7–0.9)	**54.8%** ((41.5–67.4%%)	**69.4%** ((65.6–72.9%)	**66.3%** ((59.4–72.8%)
PI + 3PI	**33.3%** ((22.9–45.2%)	**86.6%** ((79.4–92.0%)	**2.5** ((1.4–4.3)	**0.8** ((0.7–0.9)	**59.5%** ((46.0–71.7%)	**68.8%** ((64.9–72.4%)	**66.8%** ((59.9–73.3%)
CaI + GI	**41.7%** ((30.2–53.9%)	**76.9%** ((68.7–83.9%)	**1.8** ((1.2–2.7)	**0.8** ((0.6–0.9)	**50.0%** ((39.7–60.3%)	**70.4%** ((65.7–74.7%)	**64.4%** ((57.3–70.9%)
CaI + 3PI	**29.2%** ((19.0–41.1%)	**49.6%** ((40.0–59.1%)	**0.6** ((0.4–0.9)	**1.4** ((1.1–1.8)	**26.9%** ((19.7–35.5%)	52.3% ((46.4–58.2%)	**41.6%** ((34.4–49.1%)
GI + 3PI	**31.7%** ((22.8–41.7%)	**86.1%** ((77.8–92.2%)	**2.3** ((1.3–4.0)	**0.8** ((0.7–0.9)	**69.6%** ((56.5–80.1%)	**55.8%** ((51.9–59.5%)	**58.9%** ((51.8–65.8%)

PLHR: positive likelihood ratio; NLHR: negative likelihood ratio; PPV: positive predictive value; NPV: negative predictive value; CsI: Cast Index; PI: Padding Index; CaI: Canterbury Index; GI: Gap Index; 3PI: three-point index.

Table 5
Regression analysis of the association of 3 radiological indexes.

	Sensitivity (95% CI)	Specificity (95% CI)	PLHR (95% CI)	NLHR (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)
CI + PI + CaI	**59.42%** ((46.92–71.09%)	**71.37** ((65.12–77.07%)	**2.08** ((1.57–2.75)	**0.57** ((0.42–0.77)	**37.96%** ((31.60–44.77%)	**85.64%** ((81.59–88.92)	**68.65%** ((63.09–73.83%)
CI + PI + GI	**43.2%** ((33.0–53.7%)	**74.5%** ((68.0–80.3%)	**1.7** ((1.2–2.3)	**0.8** ((0.6–0.9)	**43.6%** ((35.8–51.8%)	**74.2%** ((70.3–77.7%)	**64.7%** ((59.0–70.1%)
CI + PI + 3PI	**43.88%** ((33.87–54.27%)	**75.12%** ((68.62–80.88%)	**1.76** ((1.27–2.45)	**0.75** ((0.62–0.91)	**45.74%** ((37.82–53.89%)	**73.68%** ((69.80–77.23%)	**65.02%** ((59.35–70.38%)
CI + CaI + GI	**50.5%** ((40.1–60.1%)	**69.2%** ((62.5–75.4%)	**1.6** ((1.2–2.2)	**0.7** ((0.6–0.9)	**42.9%** ((36.1–49.9%)	**75.4%** ((71.0–79.3%)	**63.4%** ((57.7–68.8%)
CI + CaI + 3PI	**51.0%** ((40.7–61.3%)	**69.8%** ((63.0–76.0%)	**1.7** ((1.3–2.2)	**0.7** ((0.6–0.9)	**44.6%** ((37.8–51.7%)	**74.9%** ((70.5–78.8%)	**63.7%** ((58.0–69.1%)
CI + GI + 3PI	**40.3%** ((31.6–49.5%)	**73.2%** ((66.1–79.5%)	**1.5** ((1.1–2.1)	**0.8** ((0.7–1.0)	**51.0%** ((43.0–59.0%)	**63.9%** ((59.9–67.7%)	**59.7%** ((54.0–72.9%)
PI + CaI + GI	**40.0%** ((30.1–50.6%)	**80.3%** ((79.2–85.5%)	**2.0** ((1.4–2.9)	**0.7** ((0.6–0.9)	**48.1%** ((39.1–57.3%)	**74.5%** ((71.0–77.8%)	**67.7%** ((62.1–72.9%)
PI + CaI + 3PI	**40.8%** ((31.0–51.2%)	**81.0%** ((74.9–86.1%)	**2.1** ((1.5–3.1)	**0.7** ((0.6–0.9)	**50.6%** ((41.5–59.7%)	**74.1%** ((70.6–77.4%)	**68.0%** ((62.4–73.2%)
PI + GI + 3PI	**32.3%** ((24.1–41.2%)	**86.3%** ((80.1–90.7%)	**2.3** ((1.5–3.6)	**0.8** ((0.7–0.9)	**61.5%** ((50.6–67.7%)	**64.7%** ((61.6–67.7%)	**64.0%** ((58.3–69.4%)
CaI + GI + 3PI	**37.9%** ((29.3–47.0%)	**79.9%** ((73.3–85.5%)	**1.9** ((1.3–2.7)	**0.8** ((0.7–0.9)	**56.6%** ((47.4–65.4%)	**65.0%** ((61.4–68.5%)	**62.7%** ((57.0–68.2%)

CsI: Cast Index; PI: Padding Index; CaI: Canterbury Index; GI: Gap Index; 3P: three-point index.

Until the introduction of the CsI, no objective assessment of the risk of SD was available [19]. Subsequently, alternative methods for assessing the quality of the cast and for estimating the SD risk in children [13–17] were developed. Malviya [17] and Mazzini [7] found that the GI was more sensitive as a predictor of failure compared to the CsI. Singh et al. assessed the reliability and practicality of the CsI and PI and reported that the PI is a practical and useful tool [20]. According to Alemdaroglu et al., the 3PI exhibited high sensitivity, specificity, and positive and negative predictive values [18]. More recently, Labronici et al. identified the CsI and GI as the best predictors for SD and recommended their use to evaluate the cast quality and to estimate the SD risk [19]. According to previous works, we found that the CsI, PI, CaI are the best predictors for SD in children with DRFs treated conservatively.

Regarding sensitivity, specificity, PLHR, NLHR, PPV, NPV, and accuracy, no single index was found to be the best radiological assessment predictor of the risk of SD. The CaI had, over the highest OR, also good statistical characteristics, additionally, had several advantages: it is the only index considering at the same time the proper padding and the correct modelling of the cast, and three different radiological assessments can be calculated with two measurements. For these reasons, the CsI, PI, and CaI are recommended.

In order to find the radiological assessment with the major predictive capacity, we investigated the association of two or more

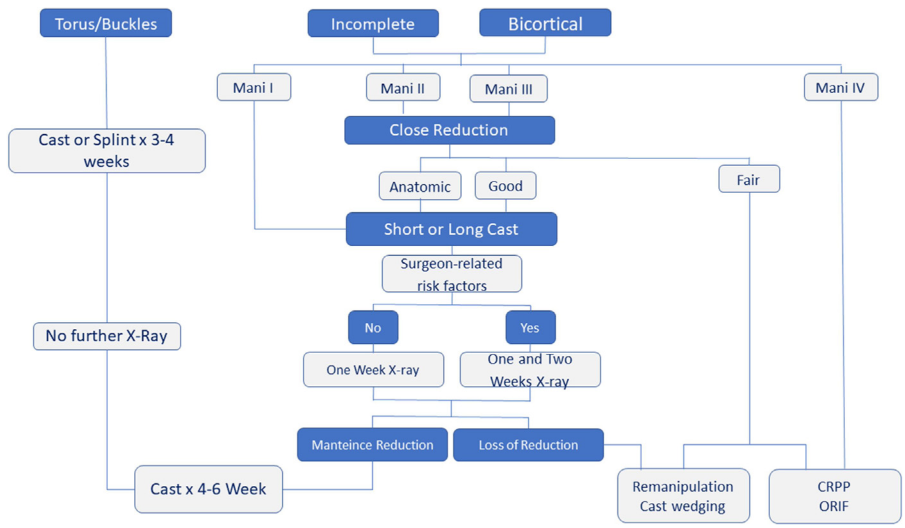

Fig. 2. Treatment algorithm for the management of distal radius fractures in children.

indeces. To the best knowledge of the authors, this is the first study to consider this association.

Higher predictor percentages were found in 2-index associations than in 3; therefore, it could be useless to associate more than 2 indexes. CsI + CaI seems to be the best predictive association with good statistical parameters (Table 3), but the CsI is included in the CaI calculation, which can generate interpretation bias; moreover, this index association did not have a better statistical percentage.

Quality of casting following reduction is important. Achieving proper cast immobilization of the facture protects against SD. In cases of inadequate reduction and poor cast quality, surgical fixation should be recommended because of the relatively high risk of early displacement [20].

Surgical management by CRPP is usually reserved for delayed treatment of displaced DRFs and for fractures with LOR and significant angulation [18]. Zamzam and Khoshhal suggested that displaced DRFs in children older than 10 years of age should primarily be reduced and pinned [18]. In our study, 52.2% of Group B had SD and were managed surgically by CRPP. Overall, surgical treatment was performed in 11.9% of our patients, suggesting that primary pinning could be an overtreatment in non-displaced DRFs and in fractures with less than 50% on both planes.

The present study had certain limitations: the retrospective design; small sample, possible radiological measurements bias.

5. Conclusion

Based on our results and on the existing literature, we attempted to provide a treatment algorithm for the management of displaced DRFs in children (Fig. 2). Non-displaced fractures should always be treated conservatively. In contrast, displaced fractures require accurate evaluation of initial translation. In particular, Mani et al. grade I fractures require CRC. Grade II and III fractures should undergo CRC; following reduction, the CsI, PI, and CaI should be measured to estimate the SD risk. If reduction is good or anatomic, and indexes are below the cutoff for SD, AP and lateral radiographs at 1-week should be performed.

However, if any surgeon-related risk factor is present, a closer clinical and radiological follow-up is mandatory. If the reduction is maintained, regardless of fracture severity, the cast should be removed after 4–6 weeks.

In patients with Mani et al. type IV fractures and poor-quality reduction, percutaneous pinning should be recommended due to the high risk of SD. Alternatively, re-manipulation of the fracture and cast wedging have been reported as a valuable alternative [17,21].

In conclusion, long arm casting represents a simple, safe, effective, and inexpensive option for the management of displaced DRFs in children. Primary surgical treatment should be reserved for Mani IV-grade fractures with poor-quality reduction due to the tendency of such fractures to become displaced [13,14]. In order to estimate the SD risk, the PI, CsI, and CaI should be measured on postoperative AP and lateral radiographs.

Disclosure of interest

The authors declare that they have no competing interest.

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Contributions

VP, AV and GT contributed equally to the work; LL and EC conceptualized and designed the article; GT and LL carried out the analysis; VP, AV and FC drafted the initial manuscript; all authors reviewed and approved the final manuscript as submitted.

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