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DISTAL METAPHYSEAL FRACTURES OF THE FOREARM IN CHILDREN- A PROSPECTIVE, OPEN, NOT RANDOMIZED PILOT STUDY AT THE DIAKONISSEN- HOSPITAL IN FLENSBURG

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CONFLICTS OF INTEREST
There are no conflicts of interest for any of the authors.

ABSTRACT

Background: The metaphyseal fracture of the distal forearm is the most common fracture in childhood. Nevertheless, so far no standard guideline for the treatment of these fractures is established in Germany.
Our objective, therefore, was to determine the criteria for conservative versus operative treatment, as well as the limiting factors for a conservative approach.

Methods: 193 patients under sixteen years of age were examined in follow-up appointments three and twelve months after a distal forearm fracture.
The kind of treatment in the first place (conservative or operative) was not dictated.

Results: As expected, all children with a torus fracture were treated conservatively. In fractures with an angulation, the treatment depended on the age of the child and on the decision of the consultant on call. The younger the child, the more often it was treated conservatively. If the malalignment/angulation was less than 20°, the children were usually treated conservatively, whereas no child with an angulation of more than 40° was treated conservatively. Twelve month after trauma there was no significant difference in function or anatomy between the two groups.

Conclusions: Although we only saw a limited number of patients, we came to the conclusion that the potential for the spontaneous correction of deformities of the distal forearm in children should be taken into account more often when deciding on a treatment plan.

INTRODUCTION

Forearm fractures are with up to 39% the most common fractures in childhood [[1]], mostly located at the distal forearm [[2]]. Historically, these fractures were treated conservatively with immobilization in a cast or closed reduction and a cast [[3],[4]]. Nowadays, conservative treatment is still a viable option for these fractures, depending on the remaining growth potential of the epiphysis.

No guideline exists to determine from which degree of angulation a surgical approach is necessary.

Nowadays surgeons seem to tend more towards an operative treatment with closed reduction and Kirschner wire fixation in the first place [[5]], perhaps caused by high secondary dislocation rates after conservative closed

reduction [6,7] and reinforced by the fact that there is no valid data to determine which degree of angulation can be tolerated at which age [1].

The aims of this study are to find out the main criteria in deciding between a conservative and an operative treatment approach and to determine if we can define safe limits for a non-surgical approach without impeding function and anatomy. Criteria for these aims are subjective well-being without pain and normal function and objective measurements with clinical scores and comparison of the axis. The idea for this study came up at the University of Lübeck, data was collected at several hospitals in northern Germany (Kiel, Lübeck, Itzehoe, Hamburg and Flensburg), most valid data was collected in Flensburg.

The positive ethics vote was given by the ethics committee of the University of Lübeck.

MATERIALS AND METHOD:

Inclusion criteria: Between August 2007 and Mai 2009 we included all patients which came to the emergency department of the Diakonissen Hospital in Flensburg (educational teaching hospital of the University of Kiel) with a fracture of the distal metaphyseal forearm. Bulging fractures, greenstick fractures (the concave corticalis still in contact the convex one without contact), complete fractures of the radius or radius and ulna and patients with an epiphysiolysis of the distal radius, younger than 16 years of age were included. In the setting an outpatient treatment or a hospitalization, a conservative or operative treatment was possible.

Exclusion criteria: Patients older than 16 years, patients with closed growth plates, fractures of the distal shaft, open fractures or congenital growth disorders were excluded. If no consent was given by the parents, the patients were excluded as well.

Number of cases: The 200 expected patients in the study protocol were sufficient for the ethics committee.

Randomisation: No randomisation was implemented. The consultant on call, belonging to the trauma surgery department of the Diakonissen Hospital Flensburg, saw all the X-rays of those patients who fulfilled the inclusion criteria and decided according to the LiLa-classification which kind of fracture it was and what the treatment should be. Exact figures for operation or conservative treatment were not set up in advance to evaluate current practices.

The observer after three and twelve months was not blinded

LiLa-classification: The LiLa-classification was established by von Laer in 2000.Similar to the AO-classification it consists of a code. The first two numbers describe the bone and the segment of the fracture in the bone, the third position differs between joint and shaft fractures, the fourth describes the morphology and the fifth the extent of displacement (0= no displacement, 1=tolerably displaced, 2=not tolerably displaced). In this classification in average at the distal radius, 10-25° are meant to be tolerably displaced, 25-35° not tolerably displaced [8]still hospitals decide subjectively if a fracture is tolerably displaced or not.

Treatment: Children, coming to the emergency department with signs of having a fracture of the distal forearm had a clinical examination including swelling, displacement, peripheral sensitivity and circulation. Afterwards an x-ray of the distal forearm in two planes (ap and lateral) was done.The fractures were classified in torus-, greenstick or complete fractures, the extent of angulation was documented in 10°steps (up to 10°, 10-20°, 20-30°, 30-40°, >40°, dislocation more than shaft width and complete displacement).

The consultant on call, decided if the angulation of the fracture and the displacement was tolerable and determined the following course of action.

Patients with no or minimal angulation/displacement of the fractures were immobilized in a cast for three to four weeks.

Fractures with a more pronounced angulation were reduced and immobilized in a cast or, reduced, fixated with a Kirschner wire and immobilized in a cast, also for three to four weeks. Fractures in the diametaphyseal zone were treated by ESIN (elastic stable intramedullary nail)-fixation.

The follow -up visits three to four weeks after trauma took part for the removal of the plaster/Kirschner wire and included an X-ray except for torus fractures.

The first follow-up examination for the study occurred three months after trauma.

Examination:

Clinically: Follow-up visits were scheduled three and twelve months after trauma. Patients were asked about pain, strength and any differences in comparison to the time before the accident. The range of motion was measured on both wrists and elbows, according to the neutral-zero-method. A malalignement of the formerly fractured extremity was documented and the length of the forearm measured.

***Radiologically**:* X-rays (ap and lateral) were done on the day of trauma (to diagnose the fracture and determine the treatment plan), after reduction if necessary and occasionally after immobilization to document consolidation. Also an x-ray was done in the event of non explicable pain.

***Cooney score**:* With the Cooney score the range of strength and function was assessed objectively. The Cooney score is an objective instrument to gain information about pain, function, range of motion and strength. The highest score is 100 points.

Data collection: Data was collected retrospectively for the day of trauma (age, gender, medical history, reason for trauma, classification of the fracture, X-ray) and prospectively for the following visits, three month and twelve months after trauma.

Statistic analysis: Data collection was performed on a prepared report form, followed by a plausibility control in Excel. The statistic analysis was done with IMB-SPSS-statistic analysis for Windows release, the presentation of the results is describing. The ordinal and nominal parameters were listed in frequencies and percentages, the continuous parameters with average and standard deviation. A level of significance of $p < 0,05$ was used. Categorial relations were calculated by the Chi-Square-Test. The differences in a constant parameter in two unattached groups was filtered out by the paired T-test.

RESULTS:

193 children (122 boys, 71 girls), between two and fifteen years of age were included in this trial between August 2007 and Mai 2009 (average age 9,6 years), three months after their accident. After twelve months 19 of these children moved to unknown addresses or the parents refused to continue the study, so 174 patients were examined until the end of the study.

Type of fracture: Except for one patient, which had a joint fracture all patients had metaphyseal fractures. As expected the biggest group was formed by torus and greenstick fractures (63,7%), 22% represented epiphyseal fractures with and without metaphyseal involvement, 13,5% were complete fractures (table 1).

Table 1: Type of fracture

Age	LiLa classification									Total
	23a30	23s10	23s11	23s12	23s20	23s21	23s22	23s31	23s32	
2	0	0	0	0	2	2	0	0	0	4
3	0	0	0	0	1	2	0	0	0	3
4	0	0	0	0	1	4	0	0	0	5
5	0	0	0	0	2	5	0	0	3	10
6	0	1	0	0	3	8	1	3	1	17
7	0	0	0	1	4	4	1	1	1	12
8	0	1	2	1	5	4	1	0	2	16
9	0	3	1	1	6	5	0	0	1	17
10	0	1	2	2	4	6	0	0	2	17
11	0	1	1	4	7	4	2	0	5	24
12	0	4	2	0	12	3	2	1	1	25
13	0	4	3	2	8	5	1	0	2	25
14	0	1	0	2	4	2	0	0	3	12
15	1	1	1	1	1	1	0	0	0	6
	1	17	12	14	60	55	8	5	21	193

Table 1. Type of fracture.

Primary malalignement: 63% of the included patients had a malalignment of 10° and less, 20,2% between 10 and 20°,7,7% between 20° and 30°, 5,2% between 30° and 40° and 3,1% had more than 40° of malalignment.

Age in years	Primary malalignment						Total
	0°	<=10°	<=20°	<=30°	<=40°	>40°	
2	2	1	1	0	0	0	4
3	1	1	1	0	0	0	3
4	1	2	2	0	0	0	5
5	3	1	2	2	0	2	10
	4	8	3	0	2	0	17
7	4	3	1	3	0	1	12
8	6	3	5	0	2	0	16
9	9	4	3	1	0	0	17
10	5	7	2	1	1	1	17
11	8	1	8	4	1	2	24
12	16	4	4	0	1	0	25
13	11	5	5	2	2	0	25
14	5	3	2	2	0	0	12
15	3	2	0	0	1	0	6
Total	78	45	39	15	10	6	193

Table 2. Primary malalignment

The overall collective was divided into two groups in accordance with the literature, the first group consisting of children up to ten years of age, the second of children between eleven and fifteen years of age. In the first group 30% out of 101 children presented with a malalignment of under 10°, 20% with a malalignment of less than 20°, 7% had an angulation under 30°, 5% less than 40° and 4% an angulation of more than 40°. In the second age group the number of fractures without an angulation (in percentage) was higher (47%), the group with a minimal malalignment lower, the other fractures were in the same range as with the younger children.

Displacement: 44% of the fractures were not displaced according to the LiLa-classification, 37% were tolerably displaced and 22% intolerably displaced, in which cases the fracture was reduced and casted or reduced, casted and fixated by Kirschner wire. In older children (average age 10, 3 years) the fractures were significantly (p=0,014) more often classified as intolerably displaced. Between the ages of two and four years that was never the case.

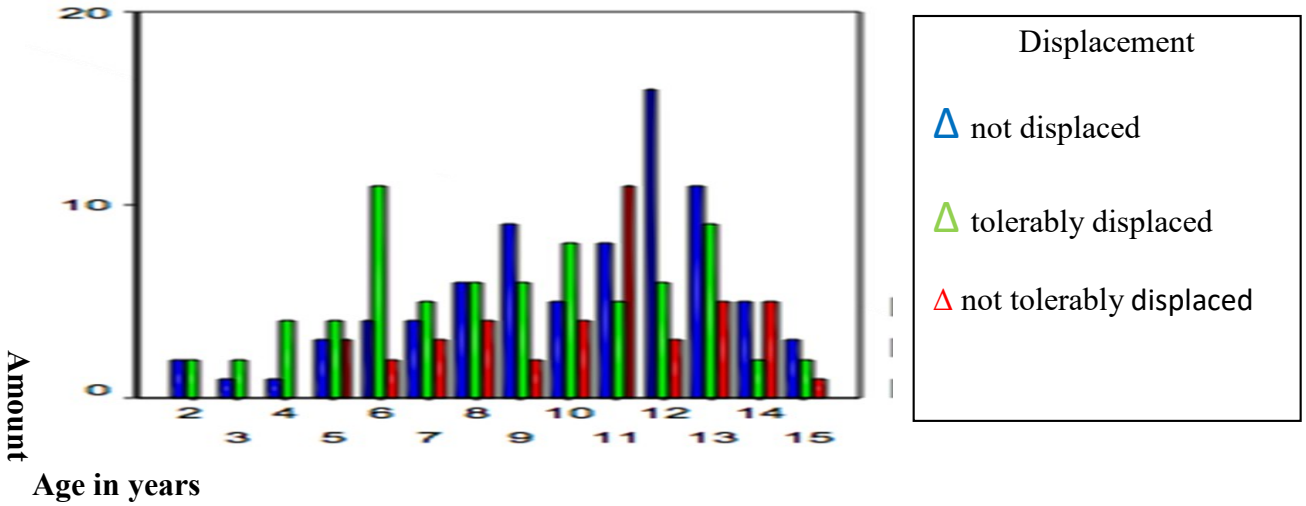

Figure 1. Displacement.

Treatment: Compared to the older age group, in the younger age group an operation was performed less frequently (18% vs. 27%), but not in a significant number. 9 patients with not tolerably displaced fractures had a simple reduction, 9 an additional Kirschner-wire-fixation. An angulation of more than 40° was tolerated in none of the groups, one of 30° was tolerated in one patient under the age of eleven (while four patients with this degree had an operation), between 20° and 30° the operation rate was still leading with one patient. A fracture with an angulation lower than 20° was usually treated conservatively.
In the older age group, malalignment of more than 30° was not accepted, one patient between 20 and 30° was treated conservatively, fractures with an angulation of less than 20° were treated conservatively (figure 3). 12 patients with not tolerably dislocated fractures had a simple reduction, 13 an additive Kirschner-wire fixation. At the Diakonissen Hospital in Flensburg plaster wedging at the distal forearm is not common and was performed in no child of our study.

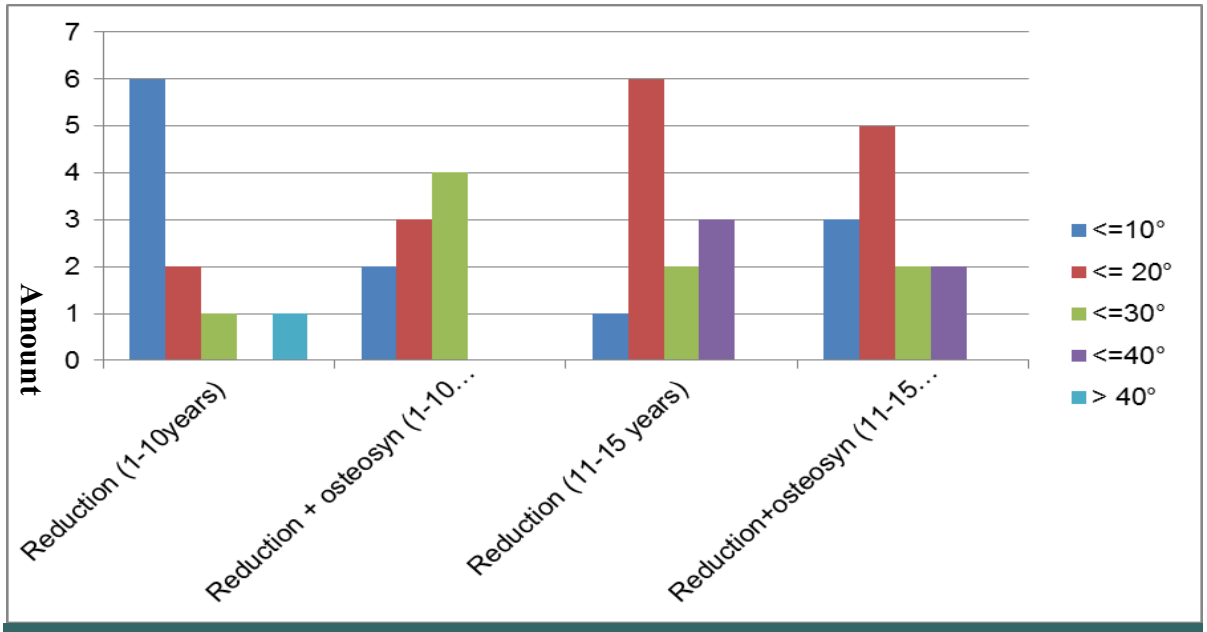

Figure 2. Treatment of not tolerably displaced fractures

In the younger age group the data showed a decreasing number of patients with an simple reduction with an increasing angulation p=0,007).
Secondary dislocation: In total, 7 children suffered from a secondary dislocation (3,6%), two out of three patients with simple reduction needed a second operation and one out of two, which had an additional osteosynthesis. In the conservative group the secondary dislocation needed no reduction.

Tolerably displaced fractures: In order to determine the potential for the spontaneous correction of deformities of the distal forearm in children, one hasnto take a closer look at the patients with tolerably displaced fractures (all not tolerably displaced fractures were operated).In our results we do not differ between fractures that were only reduced and fractures that had a reduction and Kirschner wire fixation. Excluded are also the fractures without a displacement. The remaining group in particular consisted of of 72 patients, 48 were younger than eleven years, 24 between eleven and fifteen years. In the younger age group 30 children (62,5%) had an angulation of less than 10°, 14 (29%) an angulation of less than 20°, 3 (6,2%) one of less than 30° and one patient had an angulation of less than 40°. In the second group 50% had an angulation of less than 10°, 41% of less than 20° and one child was accepted as tolerably displaced with an angulation between 20° and 30°.

	Primäre malalignment in tolerably displaced fractures				
	<=10°	<=20°	<=30°	<=40°	Total
1-10 years	30	14	3	1	48
11-15 years	13	10	1	0	24
	43	24	4	1	72

Table 3: Primary malalignment in tolerably displaced fractures

Examination three months after trauma:
After three months residual angulations ranged between 0° and 20°. On a closer look it needs a differentiation between the fractures that were operated on, where one would expect a regular anatomy directly after reduction, from the conservatively treated ones. In the younger age group, 78% of the conservatively treated patients had no angulation any more, which means an increase of 80% compared to the cases that had no angulation in the first place, 17% had an angulation of less than 10° and four cases of less than 20°. In the operated cases 83% had no malalignment, 17% a malalignment of less than 10°.
In the older age group 85% of the conservatively treated patients had no angulation, 12% one less than 10° and 2 children less than 20°. The operated ones presented with no angulation in 88% and 3 cases of less than 10°.

	Primäre malalignment in tolerably displaced fractures				
	<=10°	<=20°	<=30°	<=40°	Total
1-10 years	30	14	3	1	48
11-15 years	13	10	1	0	24
	43	24	4	1	72

Table 4: Angulation after 3 months

Examination 12 months after trauma:
After twelve months, follow-up examinations were done on 174 patients.
In the group between 2 and 10 years, 92% of the conservatively treated patients had no malalignment, 5 (6,6%) had less than 10° and one child less than 20°. In the operated group 94% had no angulation, one child less than 10°.
In the group between 11 and 15, none of the patients showed any residual angulation.
As an overall result some significant angulations could be seen after three months, with an almost complete restitutio ad integrum after twelve months. Luckily no child showed a growth disturbance.

Correction potential: For the analysis of the spontaneous correction potential one can only take into account the patients with tolerably displaced fractures. The not tolerably displaced fractures were operated and the not displaced fractures had no angulations and were treated conservatively anyway.
Out of the overall collective, 72 children fulfilled this criteria, 48 under eleven years and 24 between 11 and 15 years. The table below shows the grades of angulation.

	Primary angulation of tolerably displaced fractures				
	<=10°	<=20°	<=30°	<=40°	Total
1-10 Years	30	14	3	1	48
11-15 Years	13	10	1	0	24
	43	24	4	1	72

Table 5: Tolerably displaced fractures

Three months later 44 of those patients (61%) had no more angulation, 22 (30,6%) less than 10° and 6 children less than 20°.

Twelve months after trauma 63 of the 72 children with tolerably dislocated fractures could be reexamined. 57 patients had no more angulation, five had an angulation of less than 10° and only one child less than 20°. All angulations after 12 months were seen in the group of the younger children. No significant difference could be documented between the groups. The six children with residual angulation had a mean primary angulation of 18°, the other 66 only a mean angulation of 9°.

From the collected data, we could extrapolate a correction potential of 2,4° per month for both age groups. After three months we could only take those 27 children into account which still had an angulation. The correction potential for the following months could be quoted with 1,1° per month.

Anatomy and function:

Out of the overall collective of 193 children, those between five and fourteen years with a primary malalignment >10° and <30°, were compared (50 children). 35 children had an angulation between 10° and 20°, 15 one between 20° and 30°. In the first group 20 of those had been treated conservatively, in the second group only four. In both groups the operated children showed significantly less malalignment after three months (p=0,005 and p=0,001). After twelve months no significance was obvious any more (p=0,005, bzw. p=0,001).

Regarding the Cooney score, after three months already 97,9% of the overall collective showed good to excellent results, only one child showed bad results, after twelve months, 98,3% had excellent results, disregarding their primary degree of angulation.

	Not displaced	Tolerably displaced	Not tolerably displaced	Total
Excellent (90-100 points)	73 (93,6%)	67 (93%)	36 (83,7%)	176 (91,2%)
Good (80-90 points)	4 (5,1%)	3 (4,2%)	6 (14%)	13(6,7%)
Satisfactory (60-80 points)	1 (1,3%)	1 (1,4%)	1 (2,3%)	3 (1,6%)
Bad (<60 points)		1 (1,4%)		1 (0,5%)
Total	78	72	37	193

Table 6: Cooney Score after 3 months

	Not displaced	Tolerably displaced	Not tolerably displaced	Total
Excellent (90-100 points)	74 (100%)	61 (96,8%)	36 (97,3%)	171 (98,3%)
Good (80-90 points)		2 (3,2%)	1 (2,7%)	3 (1,7%)
Total	74	83	37	174

Table 7: Cooney Score after 12 months

DISCUSSION:

Up to now, one can find few exact data in literature concerning the spontaneous correction potential for metaphyseal fractures of the distal forearm.

As seen above after twelve months only 6 children, out of all the patients with tolerably displaced fractures, presented with a persistent angulation (8%). In five of these cases, the angulation was less than 10°, only one child had an angulation between 10° and 20°,which had a metaphyseal greenstick fracture in the first place with an palmar angulation of 22°. But even this child presented with a Cooney Score of 100 points, so no functional disability could be seen. One of the patients, at six years of age, showed complete spontaneous correction of an angulation between 30° and 40° within twelve months.

With the knowledge of our data it seems that a malalignment up to 40° can be corrected easily by children younger than eleven years, although in our study four children with fractures within this range were labelled not tolerably dislocated and operated. Similar fractures were sometimes operated, sometimes treated conservatively, which was caused by the decision, not to implement concrete treatment instructions beforehand. Therefore the surgeon on call decided the way he would in daily live. The reasons behind these treatment decisions are not obvious, which seems to make it even more important to have guidelines for conservative and operative treatment. In the age group between 11 and fifteen years an angulation up to 30° seems tolerable. Growth disturbances did not occur, neither in metaphyseal fractures nor after epiphyseal separations, so epipyseal separations are also no general criteria for an operative treatment.

In all cases a spontaneous correction occurred, although we do have to consider that the clinical results show a better outcome than the radiological results, since we initially measured the angulation radiologically, in follow-up examinations only through clinical scores. More important than the visible axis is the function of the formerly traumatized arm. In the first three months the conservatively treated children were more impaired that the patients who received surgical procedures. However, most children already showed good results after this period of time. After twelve months no difference between the two groups could be observed any more. So, within certain limits concerning the degree of angulation in fractures as well as the patients' age, a conservative approach can result in full restitution of strength and function without a painful operation.
The disadvantage of this kind of study is the missing randomization, as we saw that especially in older patients the surgeons tend to lean more towards a surgical approach. So, as could be expected, the fractures with a higher degree of angulation in patients older than ten years were always operated on, leaving no control group in this collective and causing probably better results.

Summarising the data of this study, it seems that until the age of ten a malalignment up to 40° can be tolerated, in patients up to twelve years a malalignment up to 30°, which renders reduction and plaster wedging unnecessary.

CONCLUSIONS

It appears that the potential for the spontaneous correction of deformities of the distal forearm in children should be taken into account more often when deciding on a treatment plan.

A completely prospective multicenter trial with given inclusion criteria concerning the possible angulation for certain age groups and a larger number of patients is necessary to prove this thesis.

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