Journal of Metals, Materials and Minerals. Vol. 11, No.1 pp. 22-38, 2001.

Comparative study of the three mechanical properties between the metal stylet of plastic angiocath and kirschner wire of equal diameter

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Abstract

The mechanical strength of the metal stylet of plastic angiocath was compared to Kirschner wire (k-wire) of about equal diameter. Bending, torsion and pullout strength were evaluated for three-paired size commonly used for internal fixation in Hand Surgery; 1 mm. k-wire with stylet No.16, 0.8 mm. with No.18 and 0.6 with No.20 respectively were tested. The tested revealed that metal stylet gave stronger torsional strength but weaker for pullout strength. About bending strength, only No.16 and 20 were stronger; No.18 was weaker but still stronger than 0.6 mm. k-wire. The results favor the use of metal stylet clinically.

Introduction

Plastic angiocath that commonly seen in the hospital composed of two parts. The outer sheath is made of plastic with the incur metal stylet which always be discarded in Figure 1. In microvascular surgery, plastic angiocath was widely used including our unit not for infusion but for irrigation of small vessels and again only plastic shell was used. For physical properties this discarded material was similar to k-wire in many aspects. Both produced from medical-graded stainless steel with smooth outer surface and sharp tip. The differences were that the metal stylet was hollow and the sharp tip was not located at the center in Figure 2 and Figure 3. The use of needle in Hand Surgery is not an innovation. Many surgeons use it for fixing pulp skin and distal phalanx in the child with soft bone by driving it manually. With machine driving, we have experience while performing wire loop fixation with the wire passage was made by drilling the bone with injection needle. Looking carefully, the length of metal stylet is longer and enough for use in phalangeal fixation when compared to k-wire. We noted that the metal stylet can be applied with phalangeal fixation when compared to k-wire. We noted that the metal stylet can be applied with machine without any breakage so it definitely can be used for fixation similar to the homemade cut tip k-wire with oblique not located at the center. (Namba, *et al.* 1987) However before the clinical use, we wandered about it mechanical properties when compared to k-wire and our interest was it use in Hand Surgery so we compared to k-wire of three size commonly use 1 mm. diameter, 0.8 mm. and 0.6 mm.. Because in phalangeal fixation k-wire was always placed obliquely and the movement of fingers was flexion-extension with some degrees of lateral bending and rotation so the force applied to them should be bending and torsion which were included in our study. (Vanik, *et al.* 1984; Black, *et al.* 1985; and Bozic, *et al.* 2001). The third was pullout strength, (Namba, *et al.* 1987) which was very important for smooth pin. The results are as followed.

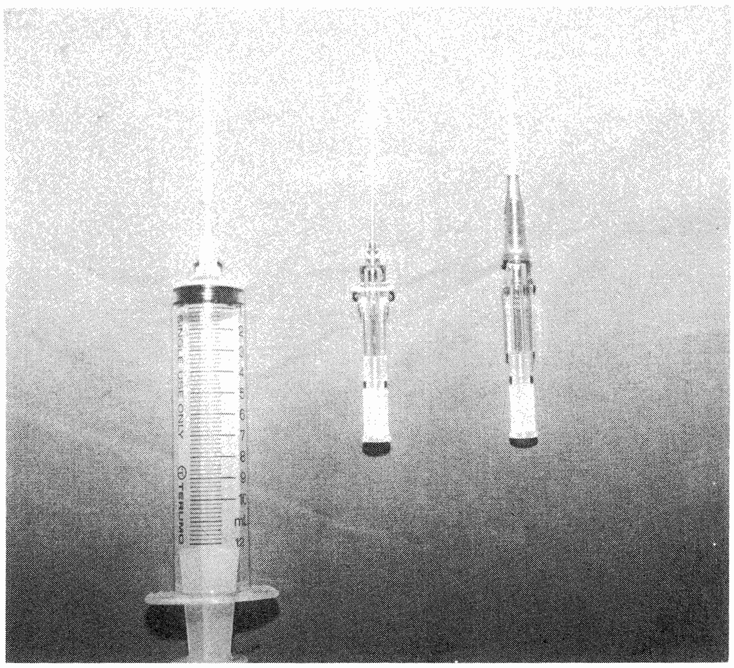

Figure 1 Plastic angiocath

Left - Outer plastic shell with syringes

Center - Metal stylet

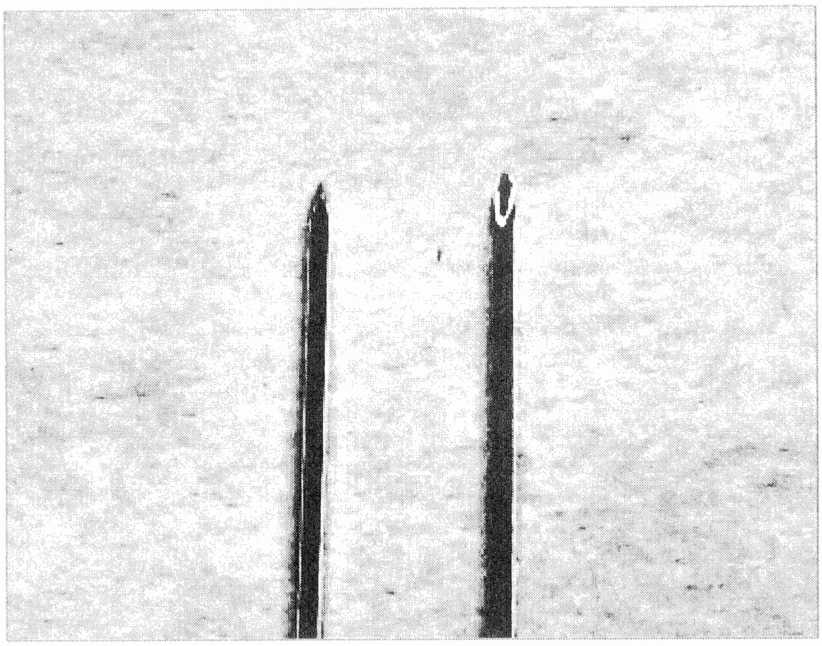

Figure 2 Left - kirschner wire - solid

Right - metal stylet – hollow.

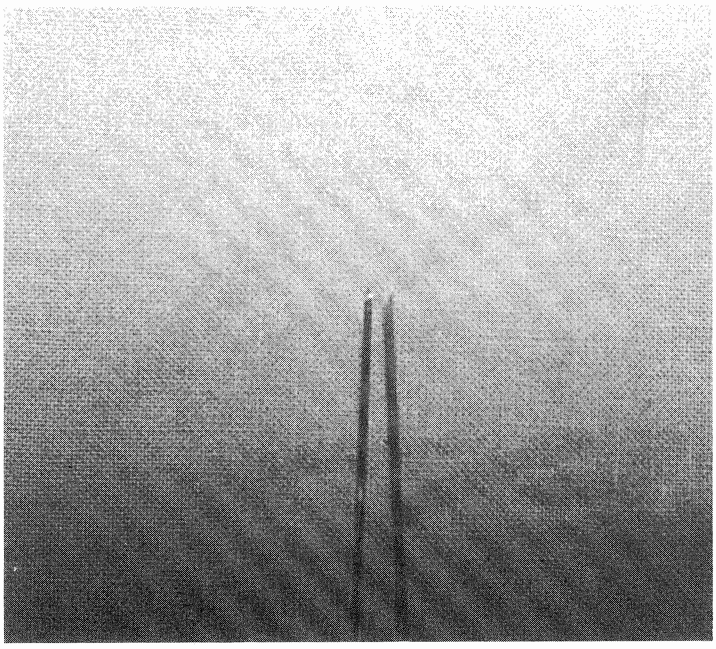

Figure 3 Tips of kirschner wire and metal stylet

Left - kirschner wire

Right - metal stylet with oblique tip

Material and Methods

The outer diameter of metal stylet (Gelco^R) No.16, 18 and 20 were compared to k-wire of 1mm. diameter, 0.8 mm. and 0.6 mm. respectively, both No.16 and 20 were equal to but No.18 was slightly smaller than 0.8 mm. k-wire. Ten specimens were tested for each group because of the homogeneous result in pilot study for all three tests.

Bending Strength (Tongrom, *et al. 2000*)

The specimens were tested with three-point bending by Universal Testing Machine in Figure 4. Crosshead speed was kept constant at 0.5 mm./sec. The maximum force at yield point was recorded and compared for each group. The results were demonstrated in Table 1, 2 and 3.

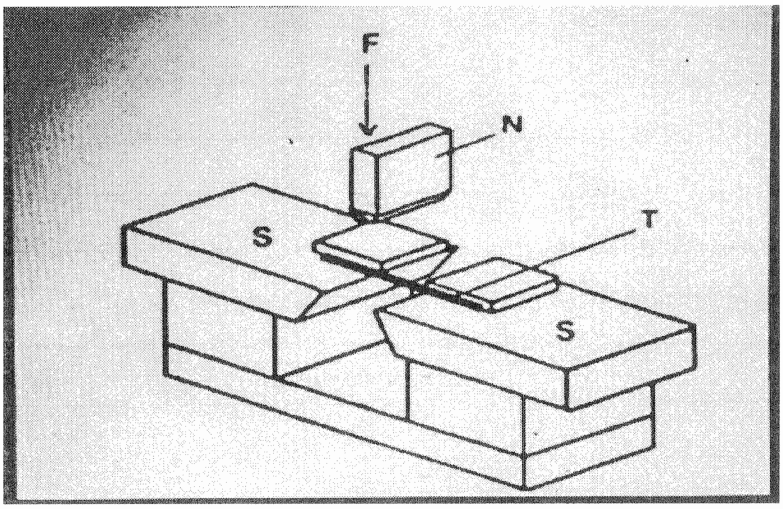

Figure 4 Three-point bending apparatus used for testing

S = supports, N = nose cone that applies load

F = maximum force recorded at time of implant failure,

T = test piece

Table 1 Bending strength of 1 mm. k-wire and metal stylet No.16

	K-wire 1.0 mm.	**Stylet No.16**
	30.097	40.51
	29.584	42.195
	29.799	42.014
	28.480	41.471
	28.445	40.600
Maximum load at yield (N)	29.675	41.071
	29.860	40.695
	30.025	41.561
	28.025	41.426
	28.335	42.220
	Mean = 29.232	Mean = 41.376
	SD = 0.765	SD = 0.612
	P = 1.79173 E-18	

Table 2 Bending strength of 0.8 mm. k-wire and metal stylet No.18

	K-wire 0.8 mm.	**Stylet No.18**
	28.32	15.26
	28.67	15.391
	27.974	15.231
	29.293	15.531
	27.874	15.156
Maximum load at yield (N)	27.775	15.627
	28.654	15.340
	28.34	15.554
	27.445	15.255
	27.510	15.471
	Mean = 28.185	Mean = 15.381
	SD = 0.551	SD = 0.15
	P = 4.5137 E-23	

Table 3 Bending strength of 0.6 mm. k-wire and metal stylet No.20

	K-wire 0.6 mm.	Stylet No.20
	5.253	9.298
	5.630	9.124
	5.591	9.211
	5.651	9.156
	5.670	9.275
Maximum load at yield (N)	5.453	9.132
	5.545	9.204
	5.260	9.174
	5.536	9.185
	5.621	9.254
	Mean = 5.521	Mean = 9.201
	SD = 0.145	SD = 0.056
	P = 1.75736 E-23	

The data was analyzed by unpaired t-test, metal stylet No.16 and 20 were stronger than 1 mm. and 0.6 mm. k-wire but No.18 was weaker than 0.8 mm. k-wire statistically significant ($p<0.05$).

Torsional Strength

Indirect torsional force was applied. The specimens were fixed at both ends to the jig in Figure 5 with resin and then the jig was connected to the Instron Series IX Automated Material Testing System in Figure 6. Because apical pole of the jig can be turned around itself when pulling force was applied longitudinally it produced torsional force to the specimens. Crosshead speed was 500 mm./min and full-scale load range was 5 KN. The forced was recorded when the machine moved to its maximum distance and compared for each group. Because of limitation of the machine, this was not represented maximum load at yield. The data was shown in Table 4, 5 and 6.

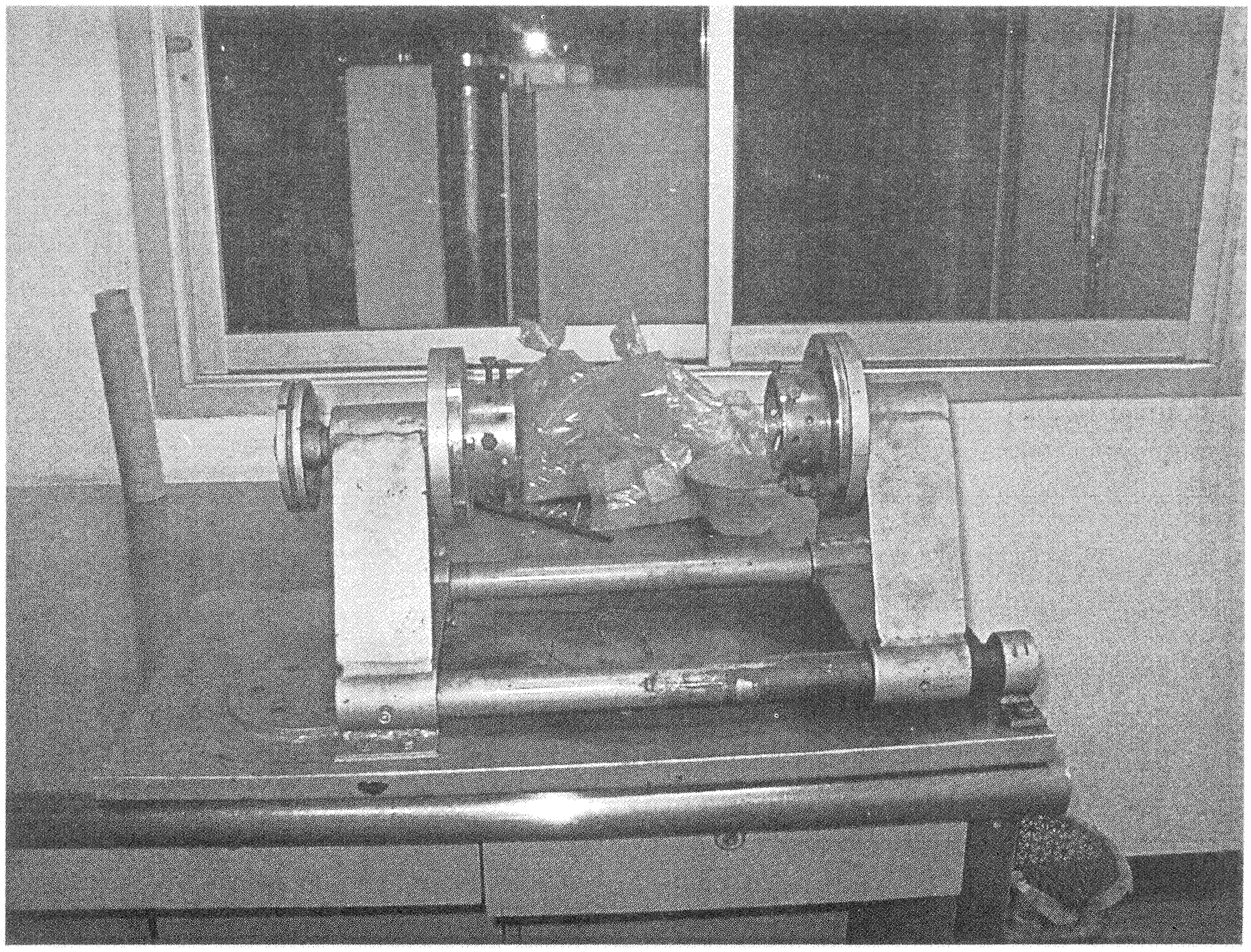

Figure 5 Jig for torsional strength test

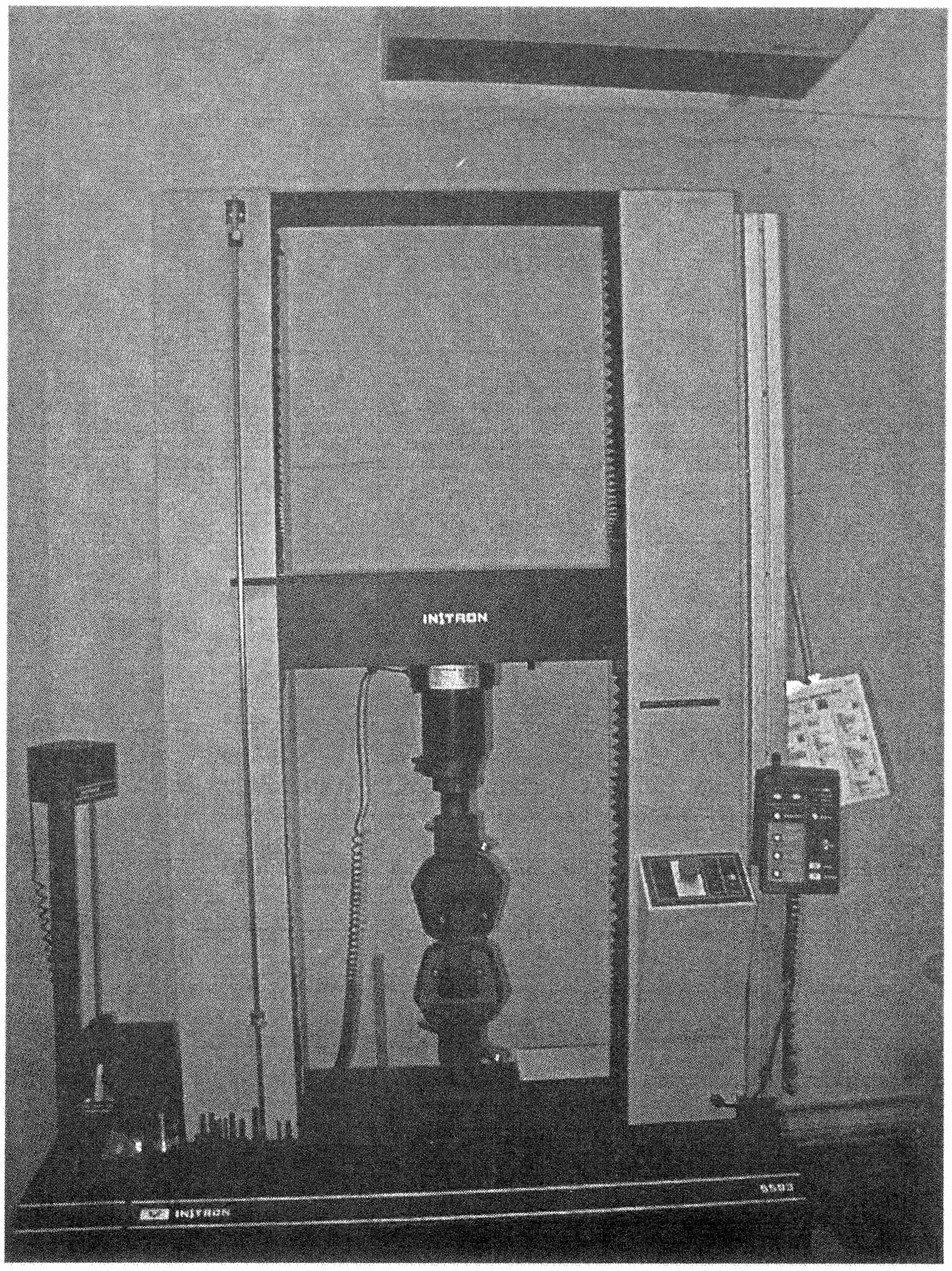

Figure 6 The Instron Series IX Automated Material Testing System

Table 4 Torsional strength of metal stylet No.16 mm. and 1 mm. k-wire (N)

	No.16	**1 mm.**
	12.471	10.211
	11.113	11.565
	10.854	9.158
	10.435	9.53
	11.359	9.741
	11.729	9.935
	10.752	10.082
	11.05	10.316
	11.433	10.261
	10.985	10.361
Mean	11.2181	10.116
Variance	0.32816832	0.407264222
Observations	10	10
Hypothesized Mean Difference	18	
df	-4.063961455	
t stat	0.000364176	
P (T<=t) one-tail	1.734063062	
t Critical one-tail	0.000728353	
P (T<=t) two-tail	2.100923666	
t Critical two-tail		

Table 5 Torsional strength of metal stylet No.18 mm. and 0.8 mm. k-wire (N)

	No.18	**0.8 mm.**
	8.356	8.132
	8.876	8.02
	8.614	7.265
	8.947	9.708
	8.878	7.588
	8.413	7.861
	8.798	7.943
	8.913	8.374
	8.652	8.219
	8.534	8.186
Mean	8.6981	8.1296
Variance	0.04628521	0.41356649
Observations	10	10
Hypothesized Mean Difference	0	
df	11	
t stat	-2.65107229	
P (T<=t) one-tail	0.0112716	
t Critical one-tail	1.79588369	
P (T<=t) two-tail	0.02254319	
t Critical two-tail	2.20098627	

Table 6 Torsional strength of metal stylet No.20 mm. and 0.6 mm. k-wire (N)

	No.18	**0.8 mm.**
	7.626	6.457
	7.089	5.908
	7.292	6.248
	7.395	6.077
	7.145	6.125
	7.316	5.956
	7.228	6.042
	7.584	6.293
	7.485	6.356
	7.199	6.259
Mean	7.3359	6.1721
Variance	0.033504989	0.031950322
Observations	10	10
Hypothesized Mean Difference	0	
df	18	
t stat	-14.38486887	
P (T<=t) one-tail	1.29601 E-11	
t Critical one-tail	1.734063062	
P (T<=t) two-tail	2.59202 E-11	
t Critical two-tail	2.100923666	

Unpaired t-test was used for statistical analysis. The metal stylet gave higher torsional strength in all compared groups.

Pullout Strength (Kositamongkon, *et al.* 2001)

Pig metacarpal was used for bone model. Each pig metacarpal was pinned with the comparing k-wire and metal stylet. The pin was placed oblique approximately 45° with the surface resemble the technique of cross-pin fixation (Massengill, *et al.* 1979; and Viegas, *et al.* 1988) by driving machine. One end of the metacarpal was rigidly fixed to the base of testing machine and pulling force was applied at the apex in Figure 7 and Figure 8. The data were shown in Table 7, 8 and 9.

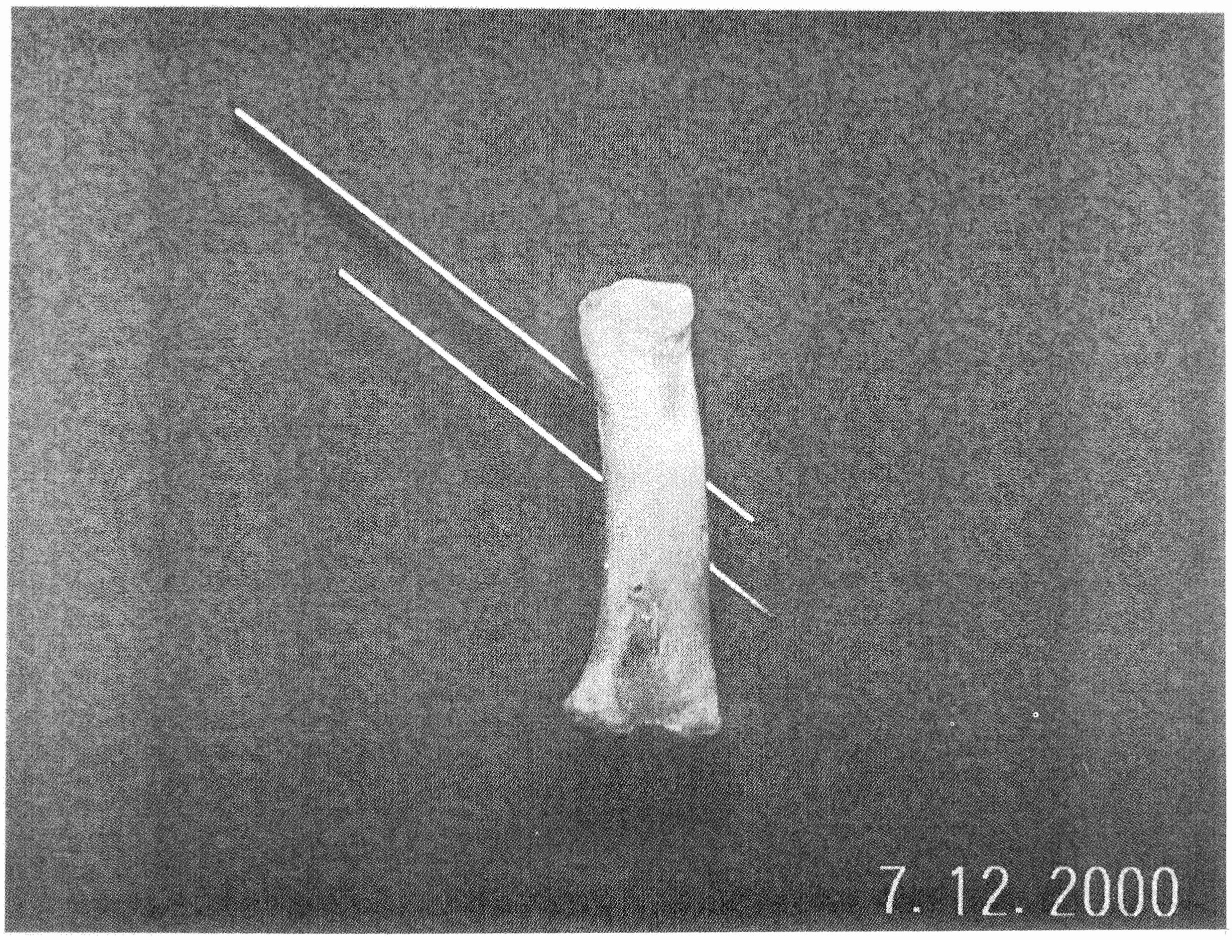

Figure 7 Pig metacarpal fixed with tested k-wire and meta stylet

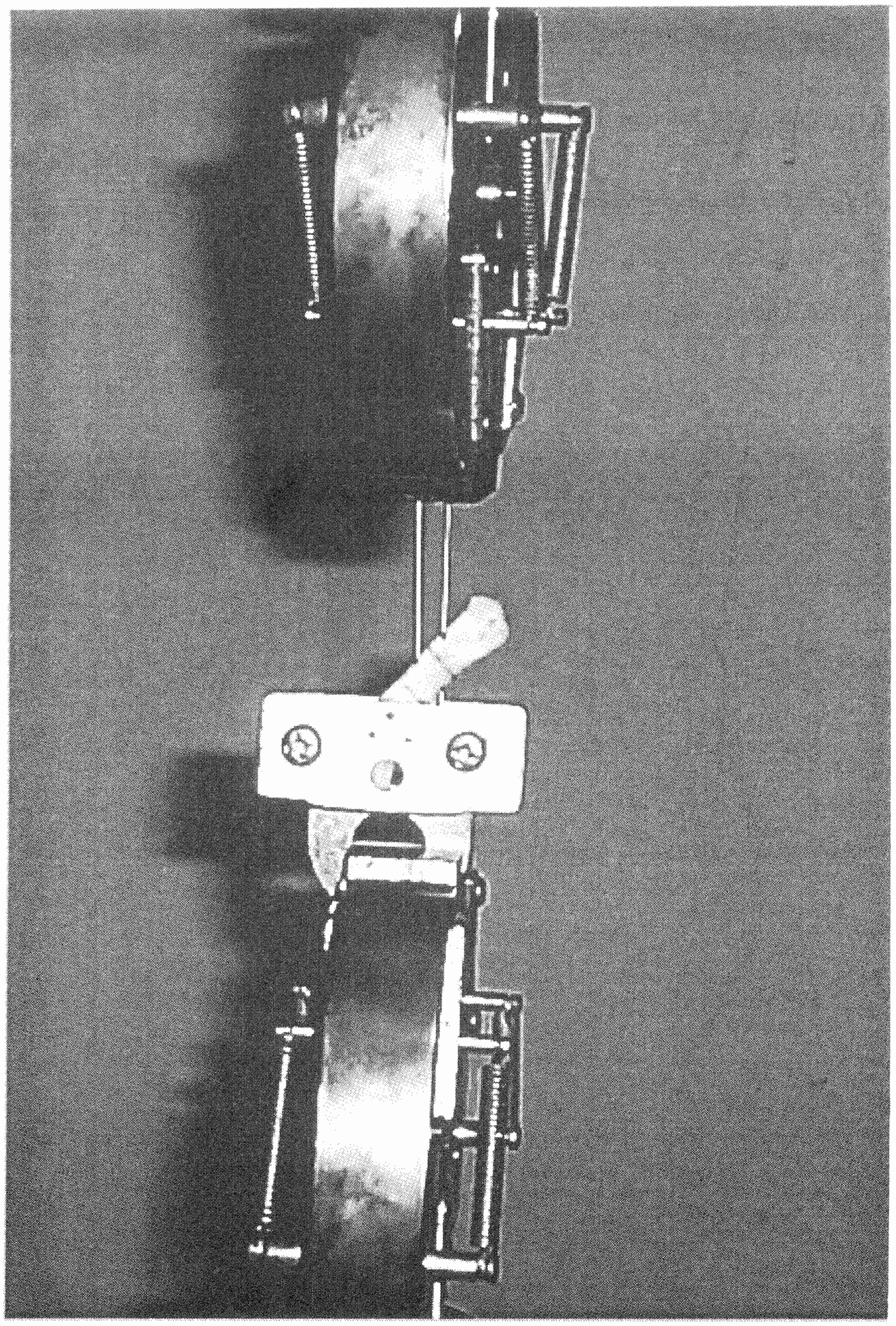

Figure 8 Pullout strength test

Table 7 Pullout strength of 1 mm. k-wire and metal stylet No.16 (N)

1 mm. K-wire	No.16
15.638	7.003
15.927	15.877
28.246	18.884
63.456	35.113
38.19	13.064
12.58	7.826
17.69	7.274
14.005	9.348
14.781	12.517
50.229	20.603
Average = 20.0742	Average = 14.7509
SD = 17.8258	SD = 8.616059
P = 0.006692	

Table 8 Pullout strength of 0.8 mm. k-wire and metal stylet No.18 (N)

0.8 mm. K-wire	No.18
13.486	13.064
8.581	8.042
23.265	7.532
15.543	9.799
12.279	5.903
10.231	6.298
14.356	5.625
14.776	5.531
31.031	10.938
13.123	8.355
Average = 15.6671	Average = 8.10879
SD = 6.656482	SD = 2.511569
P = 0.004145	

Table 9 Pullout strength of 0.6 mm. k-wire and metal stylet No.20 (N)

0.6 mm. K-wire	**No.20**
12.623	5.111
21.435	10.192
37.857	23.547
12.932	5.897
12.304	6.359
15.419	5.987
11.346	5.562
11.057	9.378
25.196	7.853
28.821	11.922
Average = 18.599	Average = 9.1808
SD = 8.481547	SD = 5.53104
P = 0.000197	

Statistical analysis revealed that metal stylet had lower pullout strength ($p<0.05$).

Discussion

With uniform results from our study we can conclude that metal stylet, the discarded material, had enough mechanical strength for clinical purpose. In our opinion the bending strength is most important because most of the finger motions are flexion and extension that bend implant directly and we were not wondered about the results because hollow material give more bending strength when compared to the solid one. For bending strength of metal stylet No.18 though it was weaker than 0.8 mm. k-wire possibly from its smaller diameter but still much stronger than 0.6 mm. k-wire. Regarding torsional strength as aforementioned it was not the main force applied to implant during normal activities of the hand, nevertheless metal stylet also gave higher torsional strength in all testing specimens. About weaker pullout strength, we thought the oblique tip should play a role as it produced larger pin tract when compared to centered tip and bending the tip more centrally will overcome this and at least it should work like the homemade cut tip k-wire which also have oblique tip and we have used for a long time without any harm. Biological viewpoint the space inside the metal stylet may cause less heat production to bone leading to better bone healing and larger pin tract produced by oblique tip pin when the time passed will create more bone formation, both of these were biological favorable. However many limitations was noted, the length of metal stylet was just suitable for small bone like metacarpal and phalanx, only one sharp end can be used because the other end cannot be cut sharp this will cause problems when perform retrograde pinning technique. We advocate its use in phalangeal fixation when antegrade pinning can be performed like transarticular pinning for tendon and ligament immobilization, fracture fixation etc. This will make this discarded material more valuable. Concerning the cost, the plastic angiocath was about one-third of the k-wire, this will be the other benefit. The hole inside the metal stylet may lead to more bacterial lodging but in our practice we routinely bend the protruded end for less irritation this will solve the problem. We have it clinically in some cases with favorable results and emphasized that this can be an alternative for temporary, antegrade pinning.

Acknowledgement

We would like to express our gratefulness to Associate Professor Pibul Itiravivong and Metallurgy and Material Science Research Institute for their help in preparing the tests.

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(Revised version accepted November 8, 2001)