RESEARCH REPORT

PORK SAFETY

Title: Developing Standardization Procedures & Conducting Product Testing for Veterinary-Use Hypodermic Devices – **NPB #00-146**

Investigator: Steven J. Hoff, PhD, PE

Institution: Iowa State University

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I. Abstract

Needles from six manufacturers were either donated or purchased for evaluating overall static and dynamic strength. Needle assemblies ranging in gage from 22, 20, 18, and 16 and needle lengths ranging from 0.50, 0.75, 1.00, and 1.50 inches were acquired. Hub materials consisting of polypropylene only, polypropylene with an aluminum insert, aluminum, stainless steel, and brass/nickel/chrome composite were tested. In total, 83 needle assemblies were tested.

Specialty testing equipment was developed to conduct the trials for this study. Three basic tests were completed, two designed to test overall static strength and one designed to test strength with simulated animal movement. Three replications of both static tests were conducted and twelve replications of the dynamic test were conducted. The over-riding goal was to provide a series of guidelines that could be used to assess needle/hub assembly performance in the field based on data collected in a controlled laboratory setting.

The major focus of this study was to determine characteristics of needle/hub assemblies that result in both desirable and undesirable failure modes in the field. An undesirable needle failure is one where the needle physically fractures after a single needle-bending event, or, a failure that involves a permanently deformed needle that could be straightened and reused. A desirable needle failure is one where, upon failure, no possibility exists for reusing the needle.

A procedure was developed that relates static testing results to anticipated failure modes expected in the field. This procedure, using a newly developed variable called the Rigidity Rating (RR) can then be used, it is hypothesized, to predict "desirable" or "undesirable" field failure conditions. Using this procedure, 100 percent of the desirable failures actually observed during simulated animal movement testing were predicted using the RR. More work is needed to further develop and refine this technique.

II. Introduction

The swine industry is quickly recognizing the importance of broken needles present in swine carcasses as they are processed at the packer. There is a wide spread interest in the industry to rid all processed cuts from broken needle hazards. Two forces are at work in this issue. First, what causes needles to break and ultimately end up in swine carcasses, and second, if a needle is present in a swine carcass, what ability do we as an industry have to identify and remove the needle?

Several different needles and needle/hub assemblies have been tested at Iowa State University. Assemblies from North America (United States and Canada) and Asia (Japan) have been tested. Through all testing procedures conducted prior to this current research project, needles remained intact with all or a portion of the hub assembly except when a needle that was permanently deformed was straightened and reused. Our conclusion to-date has been

that needles left in swine carcasses are the result of needle misuse at the farm and not a result of needle strength limitations.

The ultimate Afailure≅ condition for a needle/hub assembly is one in which upon excessive loading, as would be present during pig movement at the time of injection, the hub assembly permanently deforms, without detachment from the needle thereby preventing repeated use of the needle. In this manner, no choice exists but to discard the needle since re-use is impossible. Several needle manufacturers have a vested interest and desire to develop a needle/hub assembly that meets this criterion.

A set of strength tests for veterinary-use needle/hub assemblies has been developed at Iowa State University for evaluating the ultimate strength of needle assemblies during both static and dynamic testing. A specific standardization procedure and a complete assessment of current strength characteristics for all veterinary-use hypodermic needles used in the United States and Canada is urgently needed as the swine industry works diligently to eliminate broken needle hazards from entering the food chain.

III. Objectives

Two objectives guided this research project;

1. Provide to the industry a complete document outlining ultimate strength, load-to-failure, and the failure modes for all veterinary-use hypodermic needles used in the United States and Canada. Testing includes 16, 18, 20, and 22 gage needles varying from 2 to 1 2 inches in length and with all combinations of needles and hub material currently available.

2. Finalize a standardization procedure for testing and evaluating veterinary-use hypodermic needles identifying specific strength characteristics that result in undesirable and desirable failure modes using both static and dynamic testing procedures.

The outcome from this research project will be a consumers-report statement of the strength and failure modes for every manufactured veterinary-use needle used in the United States and Canada. A specific set of load limits and conditions of failure required for standardized use of needle assemblies in the swine industry will be determined.

IV. Procedures

This research project was intended to build upon past needle research conducted with funds provided by NPPC. In past needle research, a series of testing equipment was developed to test and simulate static and dynamic forces subjected to veterinary-use needles. This previously developed equipment worked very well and allowed for several important conclusions to be made regarding needle strength characteristics. In particular, it was concluded that most all needle fragments found in swine carcasses was the result of needle misuse. That is, if a needle was permanently deformed straightened and reused, the probability of fracturing a needle was high leaving a difficult-to-find needle fragment in the animal.

For this current funded research effort, it became apparent that the testing equipment used in the past would not suffice for a project of this magnitude. Therefore, to accomplish the objectives of this research project, a completely new set of equipment was designed and manufactured to ensure that every needle tested was being tested under identical conditions. The equipment developed to accomplish the objectives of this research project is described below:

Static Test Stand

The first device developed was one that could test needle/hub strength under static (ie. no animal movement) conditions. The static test stand developed is shown in Figure 1. This device, made entirely of aluminum, can precisely control the loading point on each needle/hub assembly. This device contains a highly accurate load cell and is completely computer controlled for conducting all desired tests. All load data and the position of the load point are stored in real-time during each test.

From this static testing unit, two basic loading conditions were tested:

Full-Embedment Test: The load point was placed at a location 1 mm from the needle/hub joint as shown in Figure 2. This static test was intended to simulate the load that would be applied to a needle if just after full embedment of the needle into the animal, the animal suddenly moved laterally away. In all discussion of the results, this test is referred to as "Test 1".

Tip-Bending Test: The load point was placed at a location 80% of the distance from the needle/hub joint to the end of the needle tip as shown in Figure 3. This static test was intended to simulate the load that would be applied to a needle if just upon injection, the animal suddenly moved laterally away before actually being injected. In all discussion of the results, this is referred to as "Test 2".

Dynamic Test Stand

A second device was developed to simulate the dynamic loads applied to a needle/hub assembly if the animal moves during and after the injection process, or, the load that might be applied with a user that violently injects an animal while in motion. The dynamic test stand, called the Animal Movement Simulator (AMS), is shown in Figure 4. This device, made entirely of aluminum, can precisely control the simulated animal speed and the point at which animal movement begins relative to the injection process. The actual needle injection zone consists of rigid polystyrene insulation board with two layers of common chamois material, intended to simulate the hide. Tests conducted on this injection area indicate a puncture force that closely matches that of a typical finishing pig. The AMS testing has no load sensing capabilities. Instead, the failure mode, if any, is categorized and compared among manufacturers. In all discussion of the results, this test is referred to as "Test 3".

AMS testing was devised to better reflect actual field condition loading situations. The failure modes recorded during this testing procedure were compared to the static loading tests to determine if any correlation could be made between these relatively simple static tests and the failures observed during AMS testing. In other words, it is entirely possible that a needle/hub assembly is superior in strength characteristics during static testing, but which has a failure mode during AMS testing that is unacceptable to the industry. Likewise, some needle/hub assemblies might not exhibit superior strength characteristics during static testing, but are resilient to unacceptable failure modes during AMS testing. AMS and static testing results were used to make these comparisons in the hope of providing useful design guidelines for the industry.

Needles Acquired

A complete search of the veterinary-use needle industry was conducted and various needles were acquired. Donations were requested and if a donation was not made, arrangements were made to purchase the required needles for testing. A total of six manufacturers were identified with a total of 83 combinations of needle gage, needle length, and hub material acquired.

Needle gages of 22, 20, 18, and 16 were received with lengths that varied between 0.5, 0.75, 1.00, and 1.50 inches. Hub materials varied between aluminum (A), polypropylene (P), polypropylene with an aluminum insert (PA), stainless steel (SS), and brass/nickel/chrome (BNC) composite. Within the polypropylene-only hubs, some manufacturers clearly used an epoxy bond between the needle and the hub in excess of what would be required to simply join the needle to the hub and these were identified as polypropylene with epoxy (PE). The complete listing of manufacturers, brand names, needle gage, needle length, and hub materials tested are shown in Tables 1a to 1d, organized by gage from 22, 20, 18, and 16 gage, respectively.

Testing Procedures

For each of the 83 needle/hub combinations tested, a separate container was filled with up to 50 randomly selected needles. All testing was then conducted from needles in these containers.

For Test 1 and Test 2, three replications were conducted. Tests were conducted to ensure that three replications was sufficient for conducting valid statistical tests. Using prior equipment from prior tests, it was determined that 5 replications were required. Three replications for the new equipment developed for conducting Test 1 and Test 2 indicates improvement in the equipment design and reproducibility. For test 3, twelve replications were conducted to yield an acceptable determination of the percent times that needle/hub assemblies would fail under various categories. For a few needle/hub assemblies supplied, it was not possible to conduct 12 replications during Test 3. For these cases, three replications were conducted.

For all 83 needle/hub assemblies tested, a second container was made to collect and store all tested needles for future reference. Therefore, 83 containers were made for each untested needle and 83 containers were made for Test 1, Test 2, and Test 3 experiments (249 after-test containers).

Failure Mode Designations

Throughout all of the testing, a description of the failure mode (if any) was made. Each failure mode designation is given below and these are referred to quite often in the results. The designations are listed in order of needle/hub failure preference. As one moves down the list of failure modes, the severity to the industry worsens.

Designation	**Description**	**Reusable?**
NONE	no visible deformation to the needle or the hub	yes
PHD	hub deforms without deformation of the needle	no
PHFI	hub fractures but remains intact as one assembly	no
PHF	hub severs leaving the assembly in two pieces	no
PND	needle permanently deforms with no hub damage	yes: after straightening
PNFI	needle itself fractures but remains as one	no: will break if straightened
PNF	needle completely severs	no

Designation	**Failure Category**
NONE	0
PHD	1
PHFI	2
PHF	3
PND	4
PNFI	5
PNF	6

For example, if a needle/hub fails (i.e. not Category 0), failure categories 1 and 2 are preferred to the industry. For these failures, the assembly remains intact but can not be reused and therefore no choice exists but to discard.

A Category 3 failure implies that upon failure, the bottom portion of the hub completely fractures leaving the needle and a portion of the hub with the animal. This type of failure does allow for relatively easy needle removal since the hub portion remaining with the needle can be easily found.

A Category 4 failure will result whenever the needle is weaker than the hub material itself. That is, if the hub is very strong and resilient to deformation, as might be the case for metal hub needles, the needle will absorb most all of the load applied to it and will permanently deform. This type of failure could be considered acceptable *if and only if a strict adherence to discarding these types of failures is observed*. However, as was mentioned before, it is clear that these types of failures are being ignored and therefore once straightened and resused, result in a high probability of needle fracture inside the animal.

Category 5 and 6 failures are completely unacceptable to the industry. With these failures, the needle will fracture upon initial bending leaving the needle directly in the animal with little hope of retrieval.

All seven failure categories listed above were observed with this research project and the characteristics that resulted in each will be discussed at great length below.

V. Results and Discussion

The results are summarized in two basic tables. Table 2 summarizes all Test 1 and Test 3 results together and Table 3 summarizes all Test 2 and Test 3 results together. The reason for including Test 3 results along with both Test 1 and Test 2 was to see if any comparisons could be made between the static tests conducted (Tests 1 and 2) and the failure modes observed during Test 3. For both Tables 2 and 3, the results are grouped by gage.

Test 1 Results

Tables 2a to 2d summarize the results for Test 1 (Full Embedment) for the 22, 20, 18, and 16 gage needles tested, respectively. Also given are the failure modes recorded during AMS testing (Test 3). A summary description of results is given below, organized by gage.

22 Gage Results

All metal hub needles (A or BNC) had a higher maximum load capability relative to all polypropylene (P, PE, or PA) hub needles tested. Metal hub needles all had maximum loads greater than 10 lbs where all P, PE, or PA hub assemblies were similar and less than 10 lbs. In all cases, Category 4 failures were observed for 100 percent of the trials.

20 Gage results

All metal hub needles (A, BNC, or SS) had a higher maximum load capability relative to all polypropylene (P, PE, or PA) hub needles tested. Metal hub needles all had maximum loads greater than 10 lbs where all P, PE, or PA hub assemblies were similar and less than 10 lbs. With the exception of one assembly tested, Category 4 failures were observed for 100 percent of the trials. In one case, the Harvard Brand SS hub, 0.75 inch needle supplied by Jorgenson Laboratories, needle fracture was observed. The needle fractured but remained intact (Category 5 failure).

18 Gage results

All metal hub needles (A, BNC, or SS) had a higher maximum load capability relative to all polypropylene (P, PE, or PA) hub needles tested. Metal hub needles all had maximum loads greater than 20 lbs where all P, PE, or PA hub assemblies were similar and less than 12 lbs. All metal hub needle assemblies had Category 4 failures for 100 percent of the trials with all P, PE, or PA hub assemblies having Category 1 failures for 100 percent of the trials.

16 Gage results

All metal hub needles (A, BNC, or SS) had a higher maximum load capability relative to all polypropylene (P, PE, or PA) hub needles tested. Metal hub needles all had maximum loads greater than 30 lbs where all P or PE hub assemblies were similar and less than 10 lbs. All metal hub needle assemblies had Category 4 failures for 100 percent of the trials with all P or PE hub assemblies having Category 1 failures for 100 percent of the trials.

Test 2 Results

Tables 3a to 3d summarize the results for Test 2 (Tip Bending) for the 22, 20, 18, and 16 gage needles tested, respectively. Also given are the failure modes recorded during AMS testing (Test 3). A summary description of results is given below, organized by gage.

22 Gage Results

For Test 2, length of needle played a dominant role in strength characteristics. The longer the needle, the lower the ultimate strength since the torque on the hub itself was higher. Maximum loads sustained were all less than 1.4 lbs.

20 Gage results

Results for the 20 gage needles were similar to the results for the 22 gage needles. Maximum loads sustained were predominantly a function of needle length. Maximum loads sustained were all less than 2.7 lbs.

18 Gage results

The general trend for 18 gage needles was similar to the 22 and 20 gage needles. As needle length increases, maximum load sustained decreases. Maximum loads sustained were all less than 6.3 lbs.

16 Gage results

The general trend for 16 gage needles was similar to the 22, 20 and 18 gage needles. As needle length increases, maximum load sustained decreases. Maximum loads sustained were all less than 11 lbs.

Test 3 Results

Test 3 data was summarized in general terms along with the strength data given for Tests 1 and 2 in Tables 2 and 3. Table 4 summarizes, in more detail, the failure conditions observed for Test 3, grouped by gage and by needle manufacturer. Shown in Table 4 is the observed percent failures in each of the seven categories listed previously.

In general, failure Categories 5 and 6 (PNFI, PNF) are unacceptable failure modes. Failure Category 4 (PND) by itself could be considered an acceptable failure mode ***if and only if*** a strict adherence to not straightening a permanently deformed needle is adopted. However, as has been determined in past studies, this appears to be the main cause of needle breakage and subsequent needles left in carcasses. Therefore, ***from strictly a theoretical point of view, Category 4 in this report is considered unacceptable to the industry***. What follows is a discussion of the results, listed in order by gage.

22 Gage Results

All needle/hub assemblies tested resulted in a Category 3 or 4 failure. If the hub was metal (A or BNC), a Category 4 failure was observed. If the hub was polypropylene and supported internally with an aluminum insert (PA), a Category 4 failure was observed. If the hub was polypropylene only, a Category 3 failure was observed for at least 92 percent of the cases.

20 Gage results

For one manufacturer, a Category 6 failure was observed. A Category 4 failure was observed for 100 percent of the cases for all metal hub needles tested. If the hub was polypropylene only, a Category 3 failure was observed for 100 percent of the cases. If the needle was less than or equal to 1.00 inches long and the hub was made of polypropylene with an aluminum insert, a Category 1 failure mode was observed for at least 92 percent of the cases. For this PA assembly at 1.50 inch needle length, a Category 4 failure was observed. Clearly, the aluminum insert added support to the hub and allowed for a more desirable failure mode up to a 1.50 inch needle length.

18 Gage results

A Category 5 failure was observed for one manufacturer using the aluminum hub needle assembly. For another manufacturer, it's SS hub resulted in a high incidence of Category 5 failures. For this manufacturer, this occurred with their "economy" line of needles. This same manufacturer, using non-economy brand needles resulted in no apparent failure. For all other cases involving metal hub needle assemblies, a Category 4 failure was observed. If the hub was made of polypropylene only, a Category 3 failure was observed. Adding an aluminum insert to the polypropylene hub moved the failure mode towards a Category 1 or 3 failure.

16 Gage results

A Category 5 failure was observed for one assembly tested for 8 percent of the trials. This same manufacturer had a Category 5 failure at the 18 gage level as well. A high incidence of Category 0 failures was observed and these were in all cases for needles less than or equal to 1.00 inches. One polypropylene manufacturer had an assortment of Category 1, 2, or 3 failures with the predominant mode at Category 2.

Relationship of Test 3 to Test 1 Failures Observed

Test 3 represents the types of failure that would be expected in the field and therefore would be considered to be a more accurate representation of clinical findings. However, from an engineering point of view, it is desirable to be able to predict clinical findings using results collected from static testing and therefore to find features in static strength characteristics that could be used to predict the failures observed in Test 3.

Characteristic Failures in Test 3 Relative to Test 1

Category 5 or 6 failures recorded during Test 3 are unacceptable to the industry. The following needle assemblies resulted in these types of failures:

Gage	Length	Hub	Manufacturer	Brand	Failure Category
20	0.75	SS	Jorgensen Laboratories	Harvard	6
18	0.75	A	Allison Medical		5
18	1.00	A	Allison Medical		5
18	1.00	SS	Jorgensen Laboratories	Economy	5
18	1.50	A	Allison Medical		5
18	1.50	SS	Jorgensen Laboratories	Economy	5
16	1.00	A	Allison Medical		5

These results, gathered using Test 3, were only found during Test 1 trials for the 20 gage, 0.75 inch long SS hub needle from Jorgensen Laboratories (Harvard Brand). For the remaining cases given above, Category 5 or 6 failures were never observed during Test 1 conditions.

The conclusion is made that as a minimum, needle/hub assemblies must "pass" Test 1 conditions. Passing Test 1 implies that after loading, the needle should deform without experiencing a Category 5 or Category 6 failure. Ultimate strength is not as important as is the ability of the needle to bend without fracturing. In other words, if the needle fractures at all during Test 1 conditions, it will surely fracture when an abrupt animal movement event is experienced during the injection process. Conversely though, if a needle does not fracture during Test 1 conditions, this does not imply that it will not fracture during animal movement conditions.

For all 22 and 20 gage needles, and if the hub material was made of metal (A, BNC, SS) or if a polypropylene hub had an aluminum insert (PA), the failure category recorded from Test 1 matched the failure category recorded for Test 3. If the hub was made of polypropylene only (P or PE), the failures observed during Test 1 did not agree with the failures observed during Test 3. In all cases of P or PE hub 20 or 22 gage needles, regardless of length, a Category 3 failure was observed 100 percent of the time during Test 3 while a Category 1 failure was observed 100 percent of the time during Test 1.

The conclusion is made that for 22 or 20 gage metal hub needle assemblies, regardless of length, the failures observed in Test 1 agreed with the failures observed in Test 3. This was not the case however for any of the 22 or 20 gage unsupported polypropylene needles.

No obvious trends like those observed for the 22 and 20 gage needles were found for the 18 and 16 gage needles. A large range of differences were observed between observed Test 1 and Test 3 failures.

Desirable Traits

If one scans the Test 3 results, there appears to be a series of needle/hub characteristics that always resulted in a failure Category between 0 and 3, without 100 percent of the failures falling into Category 3. These would be considered desirable needle/hub traits based on needle/hub failure. What follows is an analysis to try and determine what strength characteristics resulted in these traits.

From Test 3 results, the following needle/hub assemblies always resulted in a Category 0 to 3 failure, without 100 percent of the failures in Category 3:

Gage	Length	Hub	Manufacturer	Brand	Percent in Category			
					0	**1**	**2**	**3**
20	0.75	PA	Tyco Health	Monoject 251 Vet Pak		92		8
20	1.00	PA	Tyco Health	Monoject 251 Vet Pak		100		
18	1.00	PA	Tyco Health	Monoject 251 Vet Pak		33		67
18	1.50	PA	Tyco Health	Monoject 251 Vet Pak		42		58
16	0.75	A	Allison		100			
16	0.75	A	Tyco Health	Monoject 200	100			
16	0.75	BNC	Vita		100			
16	1.00	PE	PDN			8	59	33
16	1.50	PE	PDN			16	67	17

To help and determine what made these assemblies more desirable, an additional strength indicator was collected during all Test 1 and Test 2 trials in the hope that it would allow additional useful information. In Tables 2 and 3, this additional strength indicator is listed as "Max Mod E". This designation corresponds to a strength characteristic called the Modulus of Elasticity.

The Modulus of Elasticity can be interpreted as the rigidity of the needle/hub assembly. The higher the Modulus of Elasticity, the more rigid a needle/hub assembly is. The smaller the Modulus of Elasticity, the more "plastic" or spring-like the needle/hub assembly is. The Max Mod E measured during Tests 1 and 2 was defined as the maximum load versus distance of needle deformation. Again, the higher the Max Mod E, the larger the load required to deform the needle (vica versa). The table below describes the maximum load sustained for each of the desirable failures observed and the Max Mod E associated with each:

Gage	Length	Hub	Brand	Test 1		Test 2	
				Load	Mod E	Load	Mod E
20	0.75	PA	Monoject 251 Vet Pak	9.0	114	1.6	10
20	1.00	PA	Monoject 251 Vet Pak	9.3	118	1.1	7
18	1.00	PA	Monoject 251 Vet Pak	10.2	136	2.4	14
18	1.50	PA	Monoject 251 Vet Pak	9.4	126	1.7	9
16	0.75	A	Allison	54.5	787	7.6	67
16	0.75	BNC	Vita	48.5	693	7.8	62
16	1.00	PE	PDN	8.6	85	2.7	16
16	1.50	PE	PDN	8.9	98	2.2	8

Several comparison tests were conducted to try and relate either Test 1 or Test 2 results with the failure categories observed in Test 3. The hope was to find meaningful static testing data that could be used to relate clinical observations on needle/hub failures. Several comparison tests involving Test 1 and Test 2 static results were made to try and attempt this goal. Finally, the following variable, defined as the Rigidity Rating (RR) was found to predict closely the failure categories observed in Test 3:

$$\text{Rigidity Rating (RR)} = \{\text{Max Mod E} / (A * \text{Max Load} * 10{,}000)\}_{\text{Test 1}}$$

Where

Max Mod E	= maximum Load/Distance measurement recorded during Test 1 (lbs/in)
A	= cross-sectional area of the needle (in2)
Max Load	= maximum load sustained by the needle/hub during Test 1 (lbs)
10,000	= simple multiplier

The RR results are listed below for the "desirable" cases listed above:

Gage	Length	Hub	Brand	Test 1 Rigidity Rating
20	0.75	PA	Monoject 251 Vet Pak	1.58
20	1.00	PA	Monoject 251 Vet Pak	1.58
18	1.00	PA	Monoject 251 Vet Pak	1.05
18	1.50	PA	Monoject 251 Vet Pak	1.05
16	0.75	A	Allison	0.71
16	0.75	BNC	Vita	0.70
16	1.00	PE	PDN	0.49
16	1.50	PE	PDN	0.54

Using the RR concept defined above, the following limits were found for 20, 18, and 16 gage needles that yield acceptable failure conditions (Category 0, 1, 2, or 3) during Test 3 (animal movement):

If the hub is metal (A, SS, or BNC) or the hub is polypropylene with a metal inset (PA), then:

RR < 2.00 for 20 gage needles
RR < 1.20 for 18 gage needles
RR < 0.75 for 16 gage needles

If the hub is polypropylene only (P or PE), then:

RR < 1.40 for 20 gage needles
RR < 1.00 for 18 gage needles
RR < 0.55 for 16 gage needles

Using this criteria, 100 percent of the observed "desirable" failures found during Test 3 would have been predicted using the RR concept gathered using Test 1 results only. In addition however, two added "desirable" cases would have been predicted but these were not observed during actual Test 3 experiments. The two added cases that would have been predicted using this RR concept that were not observed are listed below:

Gage	Length	Hub	Manufacturer/Brand	Percent in Category				
				0	1	2	3	4
20	1.50	PA	Tyco/Monoject 251 Vet Pak					100
16	1.00	BNC	Vita	33			67	

A complete summary of all 22, 20, 18, and 16 gage needles and all RR values determined were given in Table 4.

Summary

Needles from six manufacturers were either donated or purchased for evaluating overall static and dynamic strength. Needle assemblies ranging in gage from 22, 20, 18, and 16 and needle lengths ranging from 0.50, 0.75, 1.00, and 1.50 inches were acquired. Hub materials consisting of polypropylene only, polypropylene with an aluminum insert, aluminum, stainless steel, and brass/nickel/chrome composite were tested. In total, 83 needle assemblies were tested.

Specialty testing equipment was developed to conduct the trials for this study. Three basic tests were completed, two designed to test overall static strength and one designed to test strength with simulated animal movement. Three replications of both static tests were conducted and twelve replications of the dynamic test were conducted. The over-riding goal was to provide a series of guidelines that could be used to assess needle/hub assembly performance in the field based on data collected in a controlled laboratory setting.

The major focus of this study was to determine characteristics of needle/hub assemblies that result in both desirable and undesirable failure modes in the field. An undesirable needle failure is one where the needle physically fractures after a single needle-bending event, or, a failure that involves a permanently deformed needle that could be straightened and reused. A desirable needle failure is one where, upon failure, no possibility exists for reusing the needle.

The findings from this study are as follows:

1. Needle fracture was found for some brands of needles currently being marketing after one needle bending event. These were found for Test 1 conditions, representing full-embedment loading. If a needle fractured during Test 1 conditions, it also fractured during Test 3 conditions (animal movement simulation).

2. For all 22 and 20 gage needles, and if the hub material was made of metal (A, BNC, SS) or if a polypropylene hub had an aluminum insert (PA), the failure category recorded from Test 1 matched the failure category recorded for Test 3. In other words, expected failures in the field could be gathered from Test 1 failures.

3. If the hub was made of polypropylene only (P or PE), the failures observed during Test 1 did not match the failures observed during Test 3. In all cases of P or PE hub 20 or 22 gage needles, regardless of length, a Category 3 failure was observed 100 percent of the time during Test 3 while a Category 1 failure was observed 100 percent of the time during Test 1.

4. No obvious trends like those observed for the 22 and 20 gage needles were found for the 18 and 16 gage needles. That is, Test 1 failures did not match the failures observed in Test 3 and therefore could not be used directly to predict field performance.

5. A procedure was developed that related the strength characteristics measured during Test 1 and the failures, if any, observed during Test 3. This procedure resulted in a Rigidity Rating (RR) for needles based solely on Test 1 measurements. Using RR, a prediction could be made on the type of failure to be expected in the field, with animal movement present during an injection process. For the data collected for this study, the results look promising and indicate a reasonable method for "qualifying" needle/hub assemblies based on strength. More replications however are needed to further develop and refine this procedure.

6. It appears as though laboratory measured static strength data could be used to predict field failure conditions. Currently and preliminarily, the guidelines could be stated as follows:

    a. **First**, a needle must be able to be loaded during Test 1 conditions without fracture of the needle itself. If a needle fractures during Test 1, it will fracture during field conditions leaving a portion of the needle without a portion of the hub embedded in the animal's tissue. Ultimate strength during Test 1, by itself, is not an important indicator of projected field performance. Needle integrity after Test 1 loading is the first and foremost criteria.

    b. **Second**, during Test 1 conditions, two very important measurements need to be made. First, the maximum load (Max L, lbs) supported by the needle/assembly needs to be measured. Second, the maximum load versus distance of movement needs to be recorded. For this study, this was referred to as the Modulus of Elasticity (Max Mod E).

    c. **Third**, a new variable, called the Rigidity Rating (RR), needs to be determined and calculated as:

    $$\text{Rigidity Rating (RR)} = \{\text{Max Mod E} / (\text{A} * \text{Max L} * 10{,}000)\}_{\text{Test 1}}$$

d. **Fourth**, the RR can then be used, it is hypothesized, to predict "desirable" or "undesirable" field failure conditions. As an example, and based on the results collected to date, if the following conditions are met for metal or metal supported polypropylene hub needles;

RR < 2.00	for 20 gage needles
RR < 1.20	for 18 gage needles
RR < 0.75	for 16 gage needles

Or the following conditions are met for polypropylene hub needles;

RR < 1.40	for 20 gage needles
RR < 1.00	for 18 gage needles
RR < 0.55	for 16 gage needles

then the predictions are that the needles will fail in the field "desirably" implying a Category 0, 1, 2, or 3 failure without 100 percent of the failures falling into Category 3.

Table 1a: Listing of all 22 gage needles tested.

MANUFACTURER/SUPPLIER	BRAND[1]	HUB MATERIAL[2]	LENGTH
Allison Medical		P	0.75
Allison Medical		P	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	0.75
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5
Vita Needle		BNC	1
Vita Needle		BNC	1.5

[1] No Brand Name means it is sold under the manufacturer's name.
[2] A = aluminum; P = polypropylene; PA = polypropylene with aluminum insert; PE = polypropylene with an epoxy adhesive; SS = stainless steel; BNC = brass/nickel/chrome plated

Table 1b: Listing of all 20 gage needles tested.

MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH
Allison Medical		A	1
Allison Medical		A	1.5
Allison Medical		P	0.5
Allison Medical		P	0.75
Allison Medical		P	1
Allison Medical		P	1.5
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	0.75
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1.5
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5
SuperVet		SS	0.5
SuperVet		SS	0.75
SuperVet		SS	1
SuperVet		SS	1.5
Vita Needle		BNC	0.75
Vita Needle		BNC	1
Vita Needle		BNC	1.5

Table 1c: Listing of all 18 gage needles tested.

MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH
Allison Medical		A	0.75
Allison Medical		A	1
Allison Medical		A	1.5
Allison Medical		P	0.5
Allison Medical		P	1
Allison Medical		P	1.5
Jorgensen Laboratories	Economy	SS	0.75
Jorgensen Laboratories	Economy	SS	1
Jorgensen Laboratories	Economy	SS	1.5
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5
Jorgensen Laboratories	Henke	SS	0.75
Jorgensen Laboratories	Henke	SS	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1.5
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5
SuperVet		SS	0.5
SuperVet		SS	0.75
SuperVet		SS	1
SuperVet		SS	1.5
Vita Needle		BNC	1.5

Table 1d: Listing of all 16 gage needles tested.

MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH
Allison Medical		A	0.75
Allison Medical		A	1
Allison Medical		A	1.5
Allison Medical		P	1
Allison Medical		P	1.5
Jorgensen Laboratories	Economy	SS	0.75
Jorgensen Laboratories	Economy	SS	1
Jorgensen Laboratories	Economy	SS	1.5
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5
Jorgensen Laboratories	Henke	SS	0.75
Jorgensen Laboratories	Henke	SS	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	0.75
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5
PDN		PE	1
PDN		PE	1.5
SuperVet		SS	0.5
SuperVet		SS	0.75
SuperVet		SS	1
SuperVet		SS	1.5
Vita Needle		BNC	0.75
Vita Needle		BNC	1
Vita Needle		BNC	1.5

Table 2a: 22 Gage Test 1 (Full Embedment) and Test 3 (Animal Movement Simulation) Data

				TEST 1			TEST 3
MANUFACTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE[3]	FAILURE MODE
Allison Medical		P	0.75	8.2	145	PND	PHF
Allison Medical		P	1	8.5	144	PND	PHF
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1	19.8	783	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5	19.4	823	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	0.75	8.8	135	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1	8.6	115	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1	8.5	177	PND	PHF
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5	9.3	202	PND	PHF
Vita Needle		BNC	1	14.5	488	PND	PND
Vita Needle		BNC	1.5	17.4	452	PND	PND

[3] PND = permanent needle deformation; PND/NFI = permanent needle deformation/needle fracture (intact); PNF = permanent needle fracture; PHD = permanent hub deformation; PHF = permanent hub fracture; PHFI = permanent hub fracture (intact)

Table 2b: 20 Gage Test 1 (Full Embedment) and Test 3 (Animal Movement Simulation) Data

				TEST 1			TEST 3
MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		A	1	18.8	697	PND	PND
Allison Medical		A	1.5	24.6	733	PND	PND
Allison Medical		P	0.5	8.1	109	PND	PHF
Allison Medical		P	0.75	8.6	100	PND	PHF
Allison Medical		P	1	7.8	106	PND	PHF
Allison Medical		P	1.5	7.9	116	PND	PHF
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75	22.0	857	PND & PND/NFI	PND & PNF
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1	15.9	770	PND	PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5	12.9	565	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1	14.9	653	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5	14.8	483	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	0.75	9.0	114	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1	9.3	118	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1.5	9.2	122	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1	8.6	130	PND	PHF
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5	8.3	144	PND	PHF & PND
SuperVet		SS	0.5	15.9	746	PND	PND
SuperVet		SS	0.75	14.5	667	PND	PND
SuperVet		SS	1	20.6	782	PND	PND
SuperVet		SS	1.5	14.5	657	PND	PND
Vita Needle		BNC	0.75	18.9	712	PND	PND
Vita Needle		BNC	1	21.6	540	PND	PND
Vita Needle		BNC	1.5	18.6	713	PND	PND

Table 2c: 18 Gage Test 1 (Full Embedment) and Test 3 (Animal Movement Simulation) Data

				TEST 1			TEST 3
MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		A	0.75	42.2	868	PND	PND & PND/NFI
Allison Medical		A	1	52.5	943	PND	PND & PND/NFI
Allison Medical		A	1.5	48.0	849	PND	PND & PND/NFI
Allison Medical		P	0.5	8.4	115	PHD	PHF
Allison Medical		P	1	7.6	101	PHD	PHF

Allison Medical		P	1.5	7.8	112	PHD	PHF
Jorgensen Laboratories	Economy	SS	0.75	21.5	810	PND	PND
Jorgensen Laboratories	Economy	SS	1	33.1	1130	PND	PND & PND/NFI
Jorgensen Laboratories	Economy	SS	1.5	28.8	1017	PND	PND/NFI
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75	48.9	923	PND	NONE
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1	55.3	899	PND	NONE
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5	27.3	786	PND	PND
Jorgensen Laboratories	Henke	SS	0.75	35.7	981	PND	NONE & PND
Jorgensen Laboratories	Henke	SS	1	24.7	693	PND	NONE & PND
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1	46.7	824	PND	PND
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1.5	40.7	774	PND	PND
The Kendall Company LP/Tyco Healthcare	Monoject 251 Vet Pak	PA	1	10.2	136	PHD	PND & PHF
The Kendall Company LP/Tyco Healthcare	Monoject 251 Vet Pak	PA	1.5	9.4	126	PHD	PND & PHF
The Kendall Company LP/Tyco Healthcare	Monoject 250 Needles	PE	1	10.8	151	PHD & PHF	PHF
The Kendall Company LP/Tyco Healthcare	Monoject 250 Needles	PE	1.5	10.9	159	PHD	PHF
SuperVet		SS	0.5	45.5	897	PND	PND
SuperVet		SS	0.75	40.9	1494	PND	PND
SuperVet		SS	1	27.2	1241	PND	PND
SuperVet		SS	1.5	27.5	882	PND	PND
Vita Needle		BNC	1.5	35.9	664	PND	PND

Table 2d: 16 Gage Test 1 (Full Embedment) and Test 3 (Animal Movement Simulation) Data

				TEST 1			TEST 3
MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		A	0.75	54.5	787	PND & PHFI	NONE
Allison Medical		A	1	65.8	1128	PND & PHFI	NONE & PND
Allison Medical		A	1.5	56.0	886	PND	PND
Allison Medical		P	1	9.2	150	PHD & PHF	PHF
Allison Medical		P	1.5	8.8	116	PHD	PHF
Jorgensen Laboratories	Economy	SS	0.75	43.3	1065	PND	PND
Jorgensen Laboratories	Economy	SS	1	56.2	1562	PND	PND
Jorgensen Laboratories	Economy	SS	1.5	58.8	1574	PND	PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75	53.6	942	PND	NONE & PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1	50.4	973	PND	NONE & PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5	51.3	981	PND	PND
Jorgensen Laboratories	Henke	SS	0.75	46.8	827	PND	NONE & PND
Jorgensen Laboratories	Henke	SS	1	49.4	828	PND	PND
The Kendall Company LP Tyco Healthcare	Monoject 200 Needles	A	0.75	63.4	1515	PND	NONE
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1	57.0	1189	PND	NONE & PND
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1.5	63.4	1286	PND	PND
PDN		PE	1	8.6	85	PHD & PHF	PHFI,PHF, & HD
PDN		PE	1.5	8.9	98	HD & PHD	PHFI,PHF, & HD
SuperVet		SS	0.5	57.5	935	PND	NONE & PND
SuperVet		SS	0.75	50.7	1846	PND	NONE & PND
SuperVet		SS	1	55.5	1562	PND	PND
SuperVet		SS	1.5	43.9	1126	PND	PND
Vita Needle		BNC	0.75	48.5	693	PND	NONE
Vita Needle		BNC	1	34.8	390	PND	NONE & PND
Vita Needle		BNC	1.5	45.1	762	PND & PHD	PND

Table 3a: 22 Gage Test 2 (Tip Bending by Gage) and Test 3 (Animal Movement Simulation) Data

				TEST 2			TEST 3
MANUFACTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		P	0.75	0.6	6	NONE	PHF
Allison Medical		P	1	0.5	6	NONE	PHF
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1	0.5	5	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5	0.3	4	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	0.75	1.3	12	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1	0.5	6	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1	0.7	6	NONE	PHF
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5	0.3	3	NONE	PHF
Vita Needle		BNC	1	0.6	5	NONE & PND	PND
Vita Needle		BNC	1.5	0.3	4	NONE & PND	PND

Table 3b: 20 Gage Test 2 (Tip Bending by Gage) and Test 3 (Animal Movement Simulation) Data

				TEST 2			TEST 3
MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		A	1	1.2	7	NONE	PND
Allison Medical		A	1.5	0.7	6	NONE	PND
Allison Medical		P	0.5	2.2	21	PND	PHF
Allison Medical		P	0.75	1.6	13	NONE	PHF
Allison Medical		P	1	1.0	7	PND	PHF
Allison Medical		P	1.5	0.7	5	NONE & PND	PHF
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75	1.5	10	NONE	PND & PNF
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1	1.3	9	NONE	PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5	0.7	5	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1	1.2	6	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 200 Needles	A	1.5	0.6	5	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	0.75	1.6	10	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1	1.1	7	PND	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 251 Vet Pak	PA	1.5	0.6	5	NONE	PND
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1	1.2	8	NONE	PHF
The Kendall Company LP/ Tyco Healthcare	Monoject 250 Needles	PE	1.5	0.7	5	NONE & PND	PHF
SuperVet		SS	0.5	2.7	46	PND	PND
SuperVet		SS	0.75	1.4	11	NONE	PND
SuperVet		SS	1	1.5	11	NONE	PND
SuperVet		SS	1.5	0.6	5	NONE	PND
Vita Needle		BNC	0.75	1.7	16	NONE	PND
Vita Needle		BNC	1	1.1	8	NONE	PND
Vita Needle		BNC	1.5	0.6	5	NONE	PND

Table 3c: 18 Gage Test 2 (Tip Bending by Gage) and Test 3 (Animal Movement Simulation) Data

				TEST 2			TEST 3
MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		A	0.75	4.3	35	NONE	PND & PND/NFI
Allison Medical		A	1	3.3	24	NONE	PND & PND/NFI
Allison Medical		A	1.5	2.4	18	PND	PND & PND/NFI
Allison Medical		P	0.5	3.6	31	NONE	PHF
Allison Medical		P	1	1.8	11	NONE	PHF
Allison Medical		P	1.5	1.4	7	NONE	PHF
Jorgensen Laboratories	Economy	SS	0.75	2.8	31	PND	PND
Jorgensen Laboratories	Economy	SS	1	2.5	20	PND	PND/NF I & PND
Jorgensen Laboratories	Economy	SS	1.5	1.6	9	PND	PND/NFI
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75	4.2	37	NONE & PND	NONE
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1	3.2	28	NONE & PND	NONE & PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5	1.9	13	NONE & PND	PND
Jorgensen Laboratories	Henke	SS	0.75	3.8	34	NONE	NONE & PND
Jorgensen Laboratories	Henke	SS	1	3.1	25	PND	NONE & PND
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1	3.2	31	PND	PND
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1.5	2.6	16	PND	PND
The Kendall Company LP/Tyco Healthcare	Monoject 251 Vet Pak	PA	1	2.4	14	NONE	PND & PHF
The Kendall Company LP/Tyco Healthcare	Monoject 251 Vet Pak	PA	1.5	1.7	9	NONE	PND & PHF
The Kendall Company LP/Tyco Healthcare	Monoject 250 Needles	PE	1	2.4	20	NONE	PHF
The Kendall Company LP/Tyco Healthcare	Monoject 250 Needles	PE	1.5	1.9	7	NONE	PHF
SuperVet		SS	0.5	6.2	90	NONE & PND	PND
SuperVet		SS	0.75	4.4	41	NONE	PND
SuperVet		SS	1	2.4	20	NONE & PND	PND
SuperVet		SS	1.5	1.0	7	NONE	PND
Vita Needle		BNC	1.5	1.7	21	NONE	PND

Table 3d: 16 Gage Test 2 (Tip Bending by Gage) and Test 3 (Animal Movement Simulation) Data

				TEST 2			TEST 3
MANUFCTURER/SUPPLIER	BRAND	HUB MATERIAL	LENGTH	MAX LOAD	MAX MOD E	FAILURE MODE	FAILURE MODE
Allison Medical		A	0.75	7.6	67	NONE	NONE
Allison Medical		A	1	7.2	50	NONE & PND	NONE & PND
Allison Medical		A	1.5	4.3	19	PND	PND
Allison Medical		P	1	2.7	23	NONE	PHF
Allison Medical		P	1.5	3.2	9	NONE	PHF
Jorgensen Laboratories	Economy	SS	0.75	6.5	77	PND	PND
Jorgensen Laboratories	Economy	SS	1	5.9	48	NONE	PND
Jorgensen Laboratories	Economy	SS	1.5	3.9	20	PND	PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	0.75	8.1	80	NONE & PND	NONE & PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1	6.0	46	NONE & PND	NONE & PND
Jorgensen Laboratories	Harvard Veterinary Needles	SS	1.5	3.9	20	NONE & PND	PND
Jorgensen Laboratories	Henke	SS	0.75	8.0	80	NONE & PND	NONE & PND
Jorgensen Laboratories	Henke	SS	1	6.9	53	NONE & PND	PND
The Kendall Company LP Tyco Healthcare	Monoject 200 Needles	A	0.75	8.0	80	NONE & PND	NONE
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1	6.5	43	NONE & PND	NONE & PND
The Kendall Company LP/Tyco Healthcare	Monoject 200 Needles	A	1.5	4.2	20	NONE & PND	PND
PDN		PE	1	2.7	16	NONE	PHFI,PHF, & HD
PDN		PE	1.5	2.2	8	NONE	PHFI,PHF, & HD
SuperVet		SS	0.5	11.0	205	PND	NONE & PND
SuperVet		SS	0.75	6.8	79	NONE & PND	NONE & PND
SuperVet		SS	1	6.1	48	NONE	PND
SuperVet		SS	1.5	3.3	23	NONE	PND
Vita Needle		BNC	0.75	7.8	62	NONE	NONE
Vita Needle		BNC	1	5.5	42	NONE & PND	NONE & PND
Vita Needle		BNC	1.5	3.7	24	NONE & PND	PND

Table 4a. Rigidity rating results versus 22 gage needle failures observed for Tests 1 and 3.

BRAND	HUB	LENGTH	TEST 1 MAX LOAD (lbs)	TEST 1 MAX MOD E (lbs/in)	TEST 1 RIGIDITY RATING	TEST 1 FAILURE MODE	TEST 3 Specific Percentages NONE	PHD	PHFI	PHF	PND	PNFI	PNF
ALM	P	0.75	8.2	145	3.50	PND				100.0			
ALM	P	1.00	8.5	144	3.36	PND				100.0			
MON	PA	0.75	8.8	135	3.04	PND					100.0		
MON	A	1.00	19.8	783	7.84	PND					100.0		
MON	PA	1.00	8.6	115	2.65	PND					100.0		
MON	PE	1.00	8.5	177	4.13	PND				100.0			
MON	A	1.50	19.4	823	8.41	PND					100.0		
MON	PE	1.50	9.3	202	4.30	PND				92.0	8.0		
VIT	BNC	1.00	14.5	488	6.67	PND					100.0		
VIT	BNC	1.50	17.4	452	5.15	PND					100.0		

Table 4b. Rigidity rating results versus 20 gage needle failures observed for Tests 1 and 3.

BRAND	HUB	LENGTH	TEST 1 MAX LOAD (lbs)	TEST 1 MAX MOD E (lbs/in)	RIGIDITY RATING	TEST 1 FAILURE MODE	TEST 3 Specific Percentages NONE	PHD	PHFI	PHF	PND	PNFI	PNF
ALM	P	0.50	8.1	109	1.68	PND				100.0			
ALM	P	0.75	8.6	100	1.45	PND				100.0			
ALM	A	1.00	18.8	697	4.62	PND					100.0		
ALM	P	1.00	7.8	106	1.69	PND				100.0			
ALM	A	1.50	24.6	733	3.71	PND					100.0		
ALM	P	1.50	7.9	116	1.83	PND				100.0			
JHA	SS	0.75	22	857	4.86	PND & PND/NFI					67.0		33.0
JHA	SS	1.00	15.9	770	6.04	PND					100.0		
JHA	SS	1.50	12.9	565	5.46	PND					100.0		
SUV	SS	0.50	15.9	746	5.85	PND					100.0		
SUV	SS	0.75	14.5	667	5.73	PND					100.0		
SUV	SS	1.00	20.6	782	4.73	PND					100.0		
SUV	SS	1.50	14.5	657	5.65	PND					100.0		
MON	PA	0.75	9	114	1.58	PND		92.0		8.0			
MON	A	1.00	14.9	653	5.46	PND					100.0		
MON	PA	1.00	9.3	118	1.58	PND		100.0					
MON	PE	1.00	8.6	130	1.88	PND				100.0			
MON	A	1.50	14.8	483	4.07	PND					100.0		
MON	PA	1.50	9.2	122	1.65	PND					100.0		
MON	PE	1.50	8.3	144	2.16	PND		8.0		67.0	25.0		
VIT	BNC	0.75	18.9	712	4.70	PND					100.0		
VIT	BNC	1.00	21.6	540	3.12	PND					100.0		
VIT	BNC	1.50	18.6	713	4.78	PND					100.0		

Table 4c. Rigidity rating results versus 18 gage needle failures observed for Tests 1 and 3.

BRAND	HUB	LENGTH	TEST 1 MAX LOAD (lbs)	TEST 1 MAX MOD E (lbs/in)	RIGIDITY RATING	TEST 1 FAILURE MODE	TEST 3 Specific Percentages NONE	PHD	PHFI	PHF	PND	PNFI	PNF
ALM	P	0.50	8.4	115	1.07	PHD				100.0			
ALM	A	0.75	42.2	868	1.61	PND					25.0	75.0	
ALM	A	1.00	52.5	943	1.41	PND					33.0	67.0	
ALM	P	1.00	7.6	101	1.04	PHD				100.0			
ALM	A	1.50	48	849	1.39	PND					58.0	42.0	
ALM	P	1.50	7.8	112	1.13	PHD				100.0			
JHA	SS	0.75	48.9	923	1.48	PND	67.0				33.0		
JHE	SS	0.75	35.7	981	2.15	PND	33.0				67.0		
JEC	SS	0.75	21.5	810	2.95	PND					100.0		
JHA	SS	1.00	55.3	899	1.27	PND	67.0				33.0		
JHE	SS	1.00	24.7	693	2.20	PND	33.0				67.0		
JEC	SS	1.00	33.1	1130	2.68	PND					33.0	67.0	
JEC	SS	1.50	28.8	1017	2.77	PND						100.0	
JHA	SS	1.50	27.3	786	2.26	PND					100.0		
SUV	SS	0.50	45.5	897	1.55	PND					100.0		
SUV	SS	0.75	40.9	1494	2.86	PND					100.0		
SUV	SS	1.00	27.2	1241	3.58	PND					100.0		
SUV	SS	1.50	27.5	882	2.51	PND					100.0		
MON	A	1.00	46.7	824	1.38	PND					100.0		
MON	PA	1.00	10.2	136	1.05	PHD		33.0		67.0			
MON	PE	1.00	10.8	151	1.10	PHD & PHF				100.0			
MON	A	1.50	40.7	774	1.49	PND					100.0		
MON	PA	1.50	9.4	126	1.05	PHD		42.0		58.0			
MON	PE	1.50	10.9	159	1.14	PHD				100.0			
VIT	BNC	1.50	35.9	664	1.45	PND					100.0		

Table 4d. Rigidity rating results versus 16 gage needle failures observed for Tests 1 and 3.

			TEST 1	TEST 1	RIGIDITY RATING	TEST 1	TEST 3 Specific Percentages						
BRAND	HUB	LENGTH	MAX LOAD (lbs)	MAX MOD E (lbs/in)		FAILURE MODE	NONE	PHD	PHFI	PHF	PND	PNFI	PNF
ALM	A	0.75	54.5	787	0.71	PND & PHFI	100.0						
ALM	A	1.00	65.8	1128	0.85	PND & PHFI	67.0				25.0	8.0	
ALM	P	1.00	9.2	150	0.80	PHD & PHF				100.0			
ALM	A	1.50	56	886	0.78	PND					100.0		
ALM	P	1.50	8.8	116	0.65	PHD				100.0			
JHA	SS	0.75	53.6	942	0.87	PND	33.0				67.0		
JHE	SS	0.75	46.8	827	0.87	PND	67.0				33.0		
JEC	SS	0.75	43.3	1065	1.21	PND					100.0		
JHA	SS	1.00	50.4	973	0.95	PND	33.0				67.0		
JHE	SS	1.00	49.4	828	0.83	PND					100.0		
JEC	SS	1.00	56.2	1562	1.37	PND					100.0		
JEC	SS	1.50	58.8	1574	1.32	PND					100.0		
JHA	SS	1.50	51.3	981	0.94	PND					100.0		
PDN	PE	1.00	8.6	85	0.49	PHD & PHF		8.0	59.0	33.0			
PDN	PE	1.50	8.9	98	0.54	HD & PHD		16.0	67.0	17.0			
SUV	SS	0.50	57.5	935	0.80	PND	33.0				67.0		
SUV	SS	0.75	50.7	1846	1.80	PND	33.0				67.0		
SUV	SS	1.00	55.5	1562	1.39	PND					100.0		
SUV	SS	1.50	43.9	1126	1.26	PND					100.0		
MON	A	0.75	63.4	1515	1.18	PND	83.0				17.0		
MON	A	1.00	57	1189	1.03	PND	33.0				67.0		
MON	A	1.50	63.4	1286	1.00	PND					100.0		
VIT	BNC	0.75	48.5	693	0.70	PND	100.0						
VIT	BNC	1.00	34.8	390	0.55	PND	33.0				67.0		
VIT	BNC	1.50	45.1	762	0.83	PND & PHD					100.0		

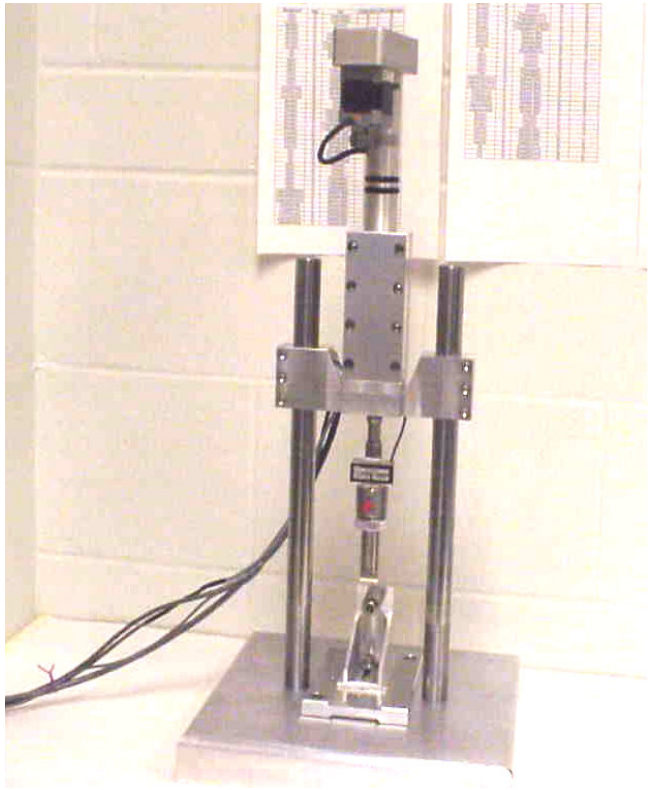

Figure 1. Static test stand used to conduct Tests 1 and 2.

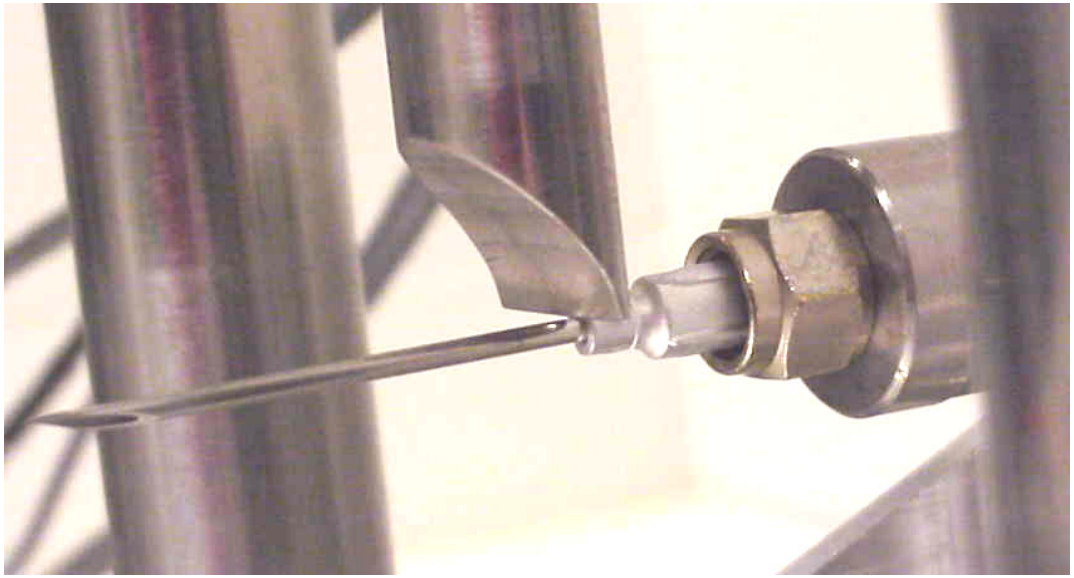

Figure 2. Test 1 set-up. Full-embedment testing.

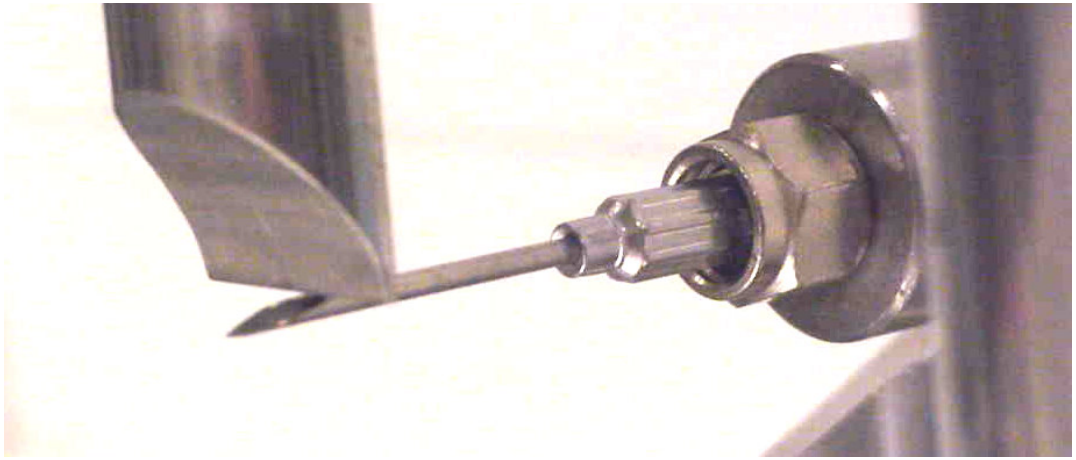

Figure 3. Test 2 set-up. Tip bending test.

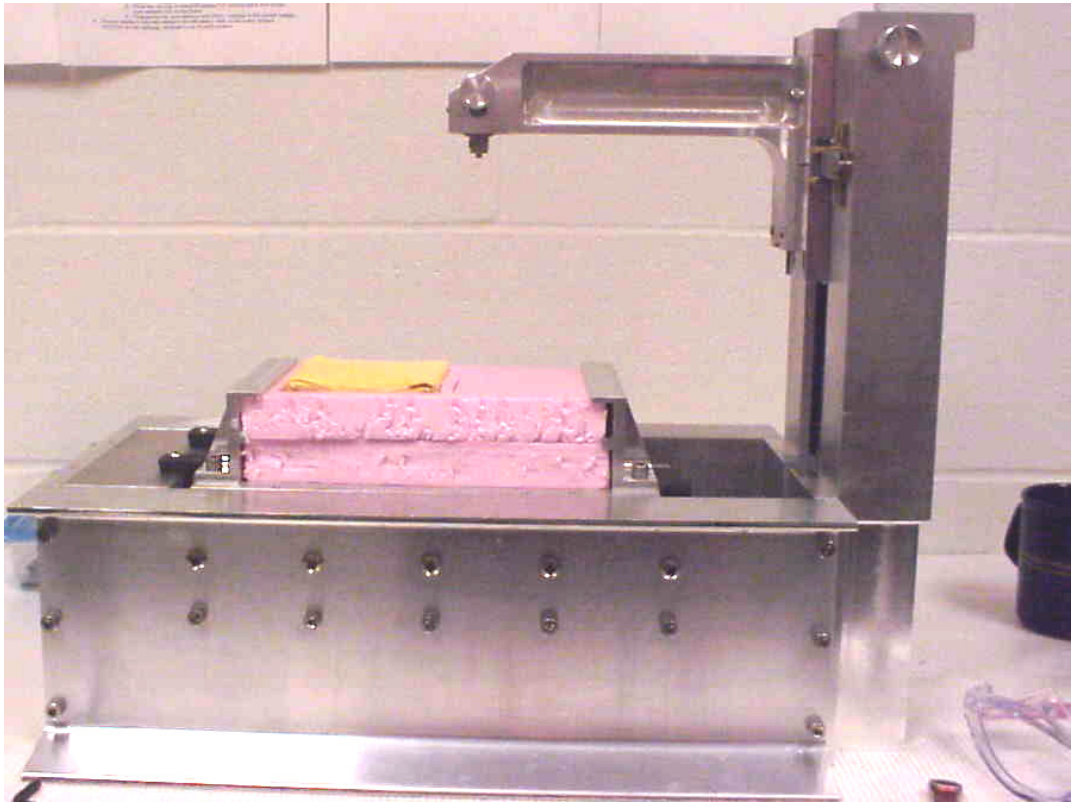

Figure 4. Test 3 set-up. Animal movement simulation test.

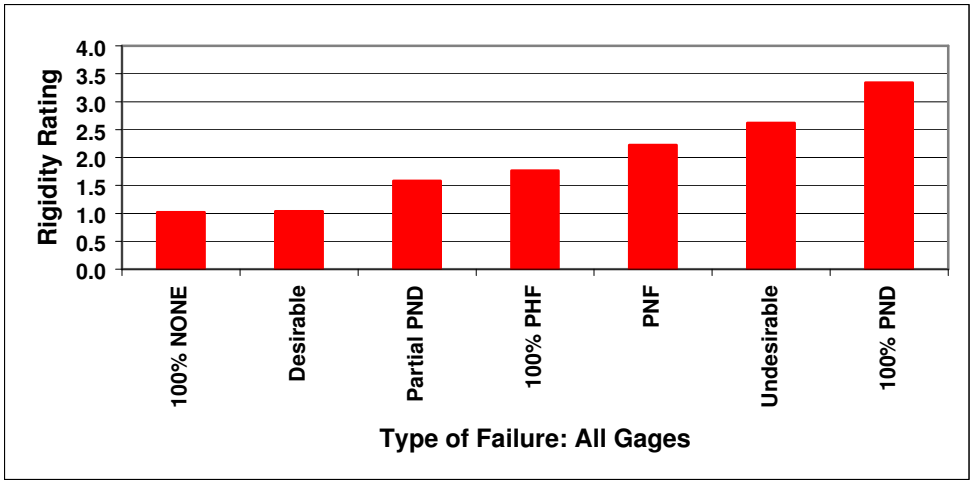

Figure 5. Rigidity Rating for all 83 needle/hub combinations tested. Some results are subsets of others or averages of others. For example, the "Desirable" category includes all Test 3 failures that fell into Category 0, 1, 2, or 3 failures without 100 percent of the failures falling into Category 3. The "Undesirable" category includes all Test 3 failures that fell into Category 4, 5, or 6 failures and all cases where Category 3 failures existed for 100 percent of the cases.

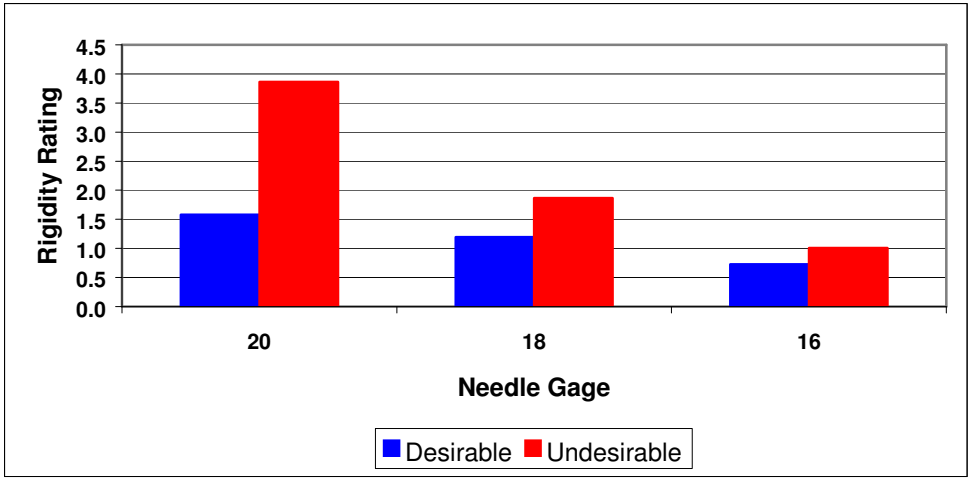

Figure 6. Rigidity Rating for all 20, 18, and 16 gage needle/hub combinations tested grouped by gage. Desirable refers to all Category 0, 1, 2, and 3 failures failures without 100 percent of the failures falling into Category 3. Undesirable refers to all other cases.

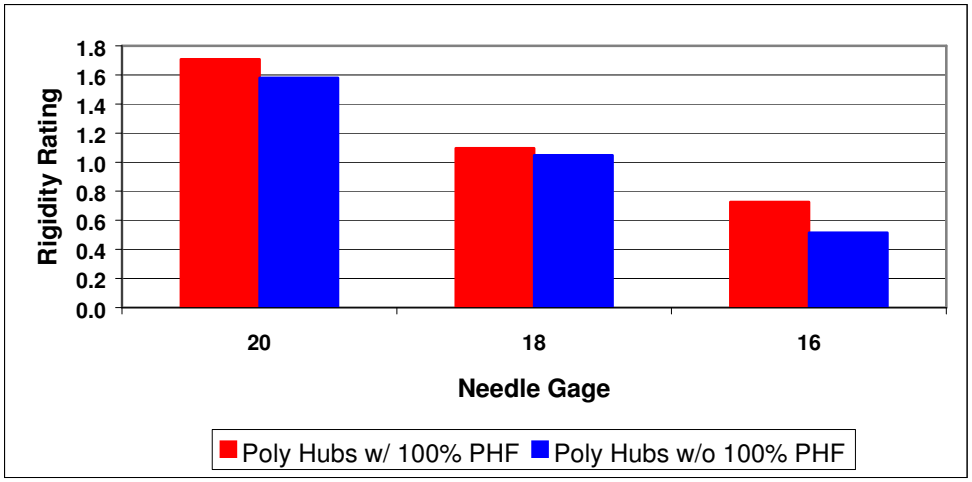

Figure 7. Rigidity Rating for all 20, 18, and 16 gage needle/hub combinations tested grouped by gage and including only those hubs made of polypropylene (P or PE) without an aluminum insert (PA).