

Original Research Paper

# Stabilization of Non-Surgical Polytrauma in Animal Limbs

Marcelo Adrián Santamaría Brunengo and Santiago Ferrándiz Bou

Department of Mechanical and Materials Engineering, Universitat Politècnica de València Doctoral School, Valencia, Spain

## Article history

Received: 13-09-2024

Revised: 13-11-2024

Accepted: 15-11-2024

## Corresponding Author:

Marcelo Adrián Santamaría  
Brunengo

Department of Mechanical and  
Materials Engineering,

Universitat Politècnica de  
València Doctoral School,  
Valencia, Spain

Email: marsanbr@masters.upv.es

**Abstract:** This project aims to identify and solve, or at least alleviate, certain problems associated with limb injuries in the veterinary area, where circumstances that are common in the medical sector have simple solutions but in animals represent long, painful processes and in a very large number of cases death, events that are easily solvable but which, due to a lack of resources or suitable devices, it is not possible to implement a timely solution. There are many injuries to which pets or livestock can be victims, many of which can be complicated or difficult to solve and require complex interventions and treatments, but limb injuries are not always so. However, especially in pets that are not dogs or cats and in livestock, they almost certainly represent, as it has already been mentioned, a condemnation to suffer a painful process of recovery without assistance or at least not the ideal one and, in a great number of cases, death. Most of the existing devices on the market have been developed from systems previously used in medicine, but there is no specific research with affordable results on the market, both in terms of availability and price. There are many variables that make the usual splints and stabilization systems not sufficiently useful in veterinary medicine, the two most important of which are. -The diversity of dimensions Between a five percentile and a 95 percentile in humans, the dimensional difference is relatively small (5 percentiles 1.53 m 47 kg 95 percentile 1.96 m 102 kg, only in dogs, the dimensional difference much bigger (5 percentiles 0.18 m 0.3 kg 95 percentile 0.8 m 105 kg) if we consider that stabilization systems have to be used even in different species, this is a big problem. Economy of scale: It is less common to treat animals than people, so veterinary systems are very costly in proportion, also considering the intrinsic value placed on human and animal life. Based on this, we have decided to delve deeper into the problem and define, based on the results of the research, consequent lines of research for the development of devices that can address the problem.

**Keywords:** Limb Injuries, Polytrauma, Splints, Stabilization, Veterinary

## Introduction

The origin of this project goes back to the request of a veterinarian specialized in canine traumatology, who in his regular work detects a series of shortcomings and difficulties when it comes to stabilizing pets, especially when they are of unusual sizes or unspecific breeds whose anatomy differs significantly from the known ones.

His intention was to have a small set of splints made in different dimensions, adaptable to his patient's measurement, especially for the pre-surgical period (Piermattei Donald and Greeley, 1996), which could be 3D printed for use in these cases and even in non-canine pets (Li and Tanaka, 2018), where, although it was not usual for him to treat them, he used to do so and where he almost never had standard resources.

## Significance of the Study

Having analyzed the needs objectively and based on the information provided, we found two clear circumstances (Son *et al.*, 2018; Zolfagharian *et al.*, 2024).

Developing the splint was not so simple since, if only for dogs, there was a diversity of types of splints for different ailments, and it was necessary to multiply it by the dimensional diversity, which, to extend it to other species, was really a much more complex challenge than what was raised in the first instance. Another key factor is that 3D printing, at least at the time work began on this project, had three major difficulties, at least at street level. Firstly, it is a very slow method (Li and Tanaka, 2018); it could even take more than a day to make a good splint, which is not usually admissible in an emergency.

Secondly, the mechanical resistance of the components, with the usual materials, was largely insufficient. We must add that most veterinarians do not have a 3D printer, sufficient knowledge, nor a legitimate interest in learning about it (Those Who Do Have a Printer Are Not Large Enough to Meet Their Needs).

The need that this veterinarian had identified had a much deeper background and was worthy of a detailed investigation to identify the scope and nuances behind the need to stabilize bone lesions in the animals that these professionals treated.

Although this veterinarian is in an environment that is not the easiest in terms of resources because, in his environment, it is not possible to provide care without looking at the necessary budget to do so, he works in a very favourable context. Reviewing situations and consulting other professionals, we discovered a quite different reality, eager for the same solution, but with a depth and a much more unappeasable closeness.

The first research found that in certain places, the poorer or less developed, the more notorious animals are not cared for due to lack of means.

The explanation is simple: things that seem obvious to many people, even professionals, such as stabilizing the leg of a dog that has suffered a fracture or tear, are not carried out in many places because either they do not have the means, or they cannot afford it, or there is simply no culture of visiting the vet (Zaera, 2022). We are always talking about domestic animals, not yet about stray animals. In many places, pets are not cared for because of a lack of means.

In many places, veterinarians must improvise to assist these animals because their patients' owners cannot afford the cost of a device to stabilize the injury, or even if they could, they are not available because it is not customary to do so (Morgan and Esther, 2019).

Just in the case of dogs and cats alone, hundreds of thousands with an owner and access to a veterinarian die every year due to lack of care. If we add to that all the pets that do not belong to this group, the figure skyrockets (Marcus, 2012).

If we go on to value farm animals (livestock and labour), the situation will become even worse.

Firstly, the intrinsic value of the life of these animals is usually comparable to their market value, i.e. a poultry is worth two kilos of chicken meat, a pig is worth fifty kilos of pork (This price on the farm, not in A Supermarket), a dairy cow is worth what she produces in milk in her remaining life plus what she would be worth sold for old cow meat (Marcus, 2012).

If a pig breaks a leg, it is simply slaughtered, even if it cannot be sold once slaughtered for whatever reason, because the cost of the vet, plus the medication, plus the care needed for treatment exceeds what the owner considers the pig to be worth. The difficulty in assisting these animals is because there are no specific devices for

them, even those that are not raised for meat, which makes their lives worthless, and so they are slaughtered (María and Julián, 2016).

Other animals, such as horses or hunting dogs, may be of greater or lesser value depending on the context, age and situation. If a jumping foal is injured and unlikely to jump again, unless it is of a coveted breed and can procreate, it is euthanized, even if its injury is recoverable from a health point of view. Stabilization resources for equines are very expensive and rare (Wright, 2022). If, on the other hand, a draught horse is injured, as it is a tool, the owner tries to recover it but finds that the resources are very expensive and, in that case, they depend on the veterinarian's ability to improvise to be able to assist it (Bromiley, 2007).

It is common to see splint bandages to prevent the Animal from moving a limb.

A hunting dog is usually an animal that has cost its owner a lot of money to buy, breed and train, yet in the event of a severe injury, it is less likely to be assisted than one that lives with a family and is kept as a pet (David & Millis, 2004). Effective and affordable stabilization devices would be an effective way to prevent these animals from being euthanized simply because of a recoverable injury (DeCamp *et al.*, 1983).

In most Western European countries or other more developed countries, if a stray animal is hit by a car, in many cases, it is taken in by animal shelters and cared for. In the rest of the world, this does not happen; if an animal suffers a fracture, it is not cared for but abandoned to its fate, even if it does not require a heroic effort to recover or if it is an animal that does not cause a greater proximity, such as a dog (Morgan and Esther, 2019).

### *Objective*

The objective is to understand the current situation in different contexts that give us an idea of the real scope of the problem at hand and, from there, begin a second phase in which we develop devices in accordance with the needs raised by professionals in different geographic areas and socioeconomic realities.

### **Materials and Methods**

To analyze the state of the art of the object of study, we decided to consult professionals in the field.

Our aim was not to identify the situation in our environment but to find out what the situation is as widely dispersed as possible since our project does not aim to make a geographically limited advance where, to a greater or lesser extent, the problems identified would be minimally covered, even if not in an ideal way, but rather to resolve problems where the situation identified is more severe, and deaths and mutilations are more common due to a lack of resources or budget (Marcus, 2012).

Having clear where we were aiming to obtain the information, we contacted veterinarians in different countries estimating the representativeness of the sample based on the prorata method, obtaining the commitment to participate from 149 veterinarians in 23 countries. In the end, only 119 responded in a timely manner.

The questions were not always commensurable; they were concepts to address circumstances of specific problems, so they had to be interpreted as they would not give us the information we needed directly. From a linear statistical model of the results, using simple programs such as Microsoft Excel, we have managed to obtain certain conclusions that define reality beyond what we can see with the naked eye in our environment and, in some cases, quantify the conditions and circumstances of the context. Below, we present the queries and analyze the responses obtained.

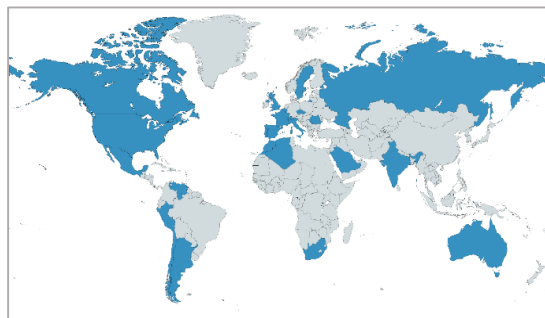
First, the geographical dispersion and the specific circumstances of the respondents should be highlighted.

At a global level, we have been able to collect information from at least some professionals in each continent, which allows us to obtain a rich geographical dispersion to take a credible reference, although it is true that in Europe and America, it was much easier to collect information than in the other continents, even when the same number of consultations were made, the feedback was not the same. The same is true for countries; some were easier to access than others.

On the map we can see in blue the countries to which the veterinarians who answered all the questions belong.

To begin the analysis, we will divide the countries from which the different veterinarians have sent us their opinions into two groups, as there is a clear difference between them in their approach to the situations based on the socio-cultural and economic conditions of each environment.

It would have been more productive if it had been possible to sectorize further, since the profile of, for example, Arab countries does not have the same profile as those in Latin America, but we do not have enough records to be able to finesse this and for the purposes of this survey the dissection into two broad groups is sufficient.



**Fig. 1:** Countries to which the veterinarians who responded to the survey belong

The division has been made between more economically and socially developed countries and developing countries. In the left column, we see the former in light blue and the latter in pink on the right.

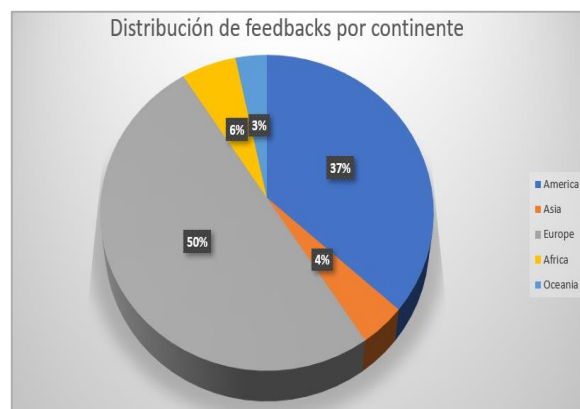
In Table (1), we can see how the feedback has been distributed among the different continents and countries where we have done the consultation.

If we consider the representativeness of each of the two groups, we see that there is a certain balance between the number of professionals who have responded in both groups (Fig. 1 and Graph 1).

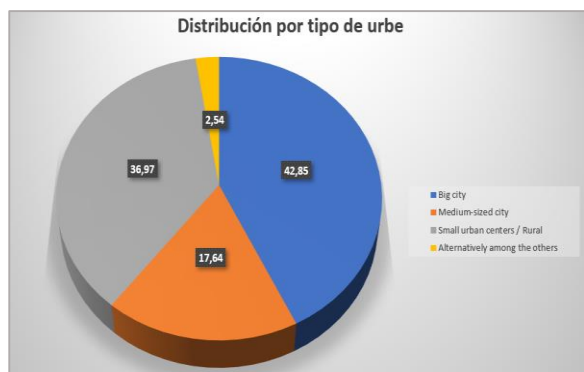
Beyond this division, it has been useful to know in which context they work in relation to the type of environment (Big City, Small Town, Rural). Of those surveyed, 43% defined themselves as belonging to a large city (more than 500,000 inhabitants), and 37% recognized that they worked mostly in rural or small urban areas (less than 15,000 inhabitants), the rest in medium-sized cities, although some alternated their work between the latter two options, the fewest of these being in a large city (more than 500,000 inhabitants) (Graph 2).

**Table 1:** Veterinarians by country are divided according to development in terms of patient access

País	Veterinarios	País	Veterinarios
Australia	4	Argelia	3
Bélgica	2	Argentina	22
EEUU	5	Chile	7
España	19	India	2
Francia	6	Marruecos	2
Italia	5	México	5
Portugal	9	Perú	2
Reino Unido	5	República Checa	5
Suecia	4	Rumanía	2
Suiza	3	Venezuela	1
Canadá	1	Arabia Saudí	1
		Sudáfrica	2
		Rusia	2
Suma	63	Suma	56
Total	119		



**Graph 1:** Distribution of feedback by continent



**Graph 2:** Distribution by type of city

This is a representation of that distribution, which is fundamental to understanding some of the responses, as well as the type of countries to which they belong.

## Results and Discussion

Below are the specific questions for the content to be assessed.

### *What Devices Do You Use to Stabilize Limb Fractures? (Graph 3)*

It is worth noting that all veterinarians stressed that depending on the case, they use one method or another, although in general, they are very likely to use exclusively the method that they consider to be the most efficient or, within the available resources, the one that will best respond to the patient's needs.

31.08% of respondents indicated that they mostly use Robert Jones (JBB) bandages, implemented in both veterinary medicine and medicine, which have the advantage that they do not require specific materials or sized to the scale of the patient, but stabilization is not complete and in theory, they are temporary tool.

A JBB consists of placing the layers of the bandage neatly and firmly, approximately fifteen centimetres above and below the joint, to be treated if it is the injury. It is recommended that it is approximately 5 centimetres thick. First, a layer of cotton is applied to slightly compress soft tissues and immobilize fractures without affecting blood circulation. These bandages are often used for short-term immobilization. An important advantage is that it generates uniform pressure which reduces oedema in fractures and/or the risk of compartment syndrome of the extremities.

We must insist that this method is a temporary stabilization system, which can help in the treatment in many cases, but it is not a definitive solution, although due to a lack of resources or specific devices, it may end up being a good option.

One of the major disadvantages of this system is that it is a slow process and requires a lot of material that cannot be reused even on the same Animal after a dressing, so if required, a new stabilization must be performed. An

important advantage is that in the case of wounds, the bandage is fully compatible with the healing of the wound, although it would require disassembly and complete discarding of the bandage, even if the wound is small.

The vast majority, 51.24%, indicated that the most common solution for this was splinting.

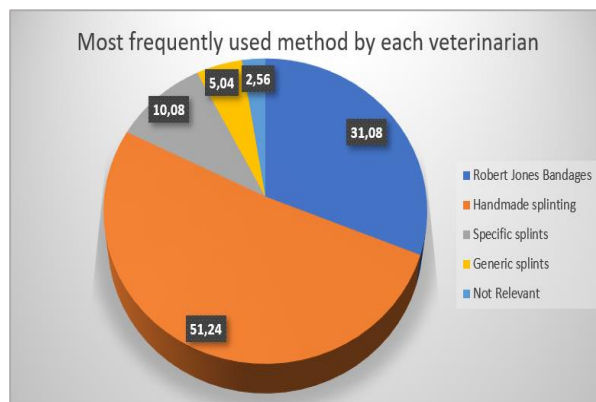
Splinting consists of supporting the limbs with rigid supports such as boards, tubes, rods, or straight splints. After padding the area, it is stabilized and secured with bandages so that it does not move.

It is an economical and very flexible method, since no matter the size and weight of the patient, a larger or smaller rod can always be found, but it has some important disadvantages.

To begin with, it is very prone to loosening, especially if the Animal is strong. We must bear in mind that we can tell a human patient not to touch the bandage, not to get wet, not to scratch, but not an animal. Another disadvantage is that, although we can opt for improvised devices of different sizes, it is not usual to have a wide range of "objects" to stabilize in clinics, so the word improvise becomes more relevant.

Another disadvantage is that, in the case of a wound or surgical suture, it is unlikely that the patient can be healed without removing the stabilization, which, considering that he will not stay still no matter how much we tell him to remove the splint, it is possible that the healing of a wound will delay the bone suture.

It has two great advantages. The main one, already mentioned, is being able to use different objects to stabilize the patient, regardless of their size; the other is its low price, as it uses everyday items and much less bandaging than a JBB, as well as the fact that a large part of it can be reused. 10.08% recognized the use of splints specific to each injury and Animal. These veterinarians coincide in first-world countries and in large cities. In these cases, as we have seen, the intrinsic value of a pet's life is much higher than what is usually assigned to it in a third-world country, adding to the great difference in the purchasing power of the clients of these clinics.



**Graph 3:** Most frequently used method by each veterinarian

Only one of these veterinarians was from a non-developed country (Argentina) but he was exclusively dedicated to the treatment of riding horses.

These splints are not extremely expensive considering the price of other services in these countries, but they are prohibitively expensive in developing countries and rare in small towns in large countries. Furthermore, they are not available for all species, sizes and injuries and can only be used in the most statistically frequent cases or in some cases where splints can be adapted.

They can usually be slightly modified, and many of them have dies to be cut according to the size of the Animal, although they are not valid for all cases; for example, the same fibula splint is not suitable for a Great Dane and trimmed for a Chihuahua.

There are also generic splints, which, depending on their size, can stabilize a human wrist as well as a fox's elbow. The most common are the typical aluminium splints with foam padding, which can be moulded to the shape of the limb but have very limited use due to their dimensions and mechanical strength and could be considered more akin to a splint than a specific splint. This type of restraint was used by 5.04% of respondents as the most common method.

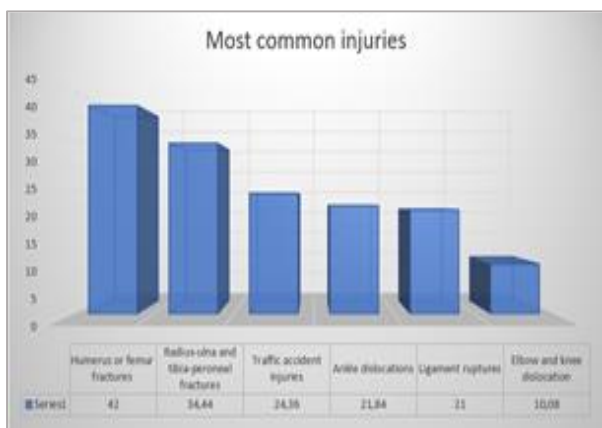
A minority of less than 3% (2.56%) responded that they do not do this type of work or gave irrelevant answers.

Surprisingly, none of the respondents referred to devices created by additive manufacturing, 1 *et al.* one pre-scanning of the Animal for splint fitting.

Which injuries are most common, in your opinion?

Regarding this question, there was quite a wide dispersion, especially considering the different sectors in which the veterinarians surveyed work. The references we will see add up to more than 100% as many vets refer to several at the same time (Graph 4).

Taking into consideration that we are talking about limb stabilization, almost all agree that the most common injuries are fractures of the humerus or femur, specifically 42%.



Graph 4: Most common injuries

Also relevant are radius-ulna and tibia-peroneal injuries, which are also mentioned by 34.44%, although it is quite common for them to require surgery to be resolved, as it is the case with femur injuries.

In the sum of both types of injuries, we find an important fact: together with hip injuries, they are the ones that generate the greatest number of avoidable deaths, as they tend to be injuries that are not always treated due to the relative difficulty of recovery in the case of pets and rarely in the case of livestock. If we were talking about humans, it would be unthinkable not to recover from these injuries, while in animals, they very often lead to the patient's sacrifice or, even worse, death due to lack of care after a long convalescence.

Some 24.36% speak of or refer to road traffic accident injuries, including hip injuries, as relevant despite not being the field of study. Some even insisted on this issue outside the survey, as there is a specific problem to be solved when surgery is not necessary and often ends up being performed due to the lack of an adequate exoskeleton.

Another very common injury, according to the reviews, is ankle dislocations, which are easier to resolve with proper stabilization and which do have specific splints, although with limited dimensional diversity, as there are mostly dogs, while other animals do not have the option. In this case, we are talking about more than 21.84% of respondents.

These lesions, which are not bony and have devices on the market, are nevertheless very important for our project because, on the one hand, as we have said, they are only available for certain animals, almost all of them for dogs. For most contexts, they are expensive, and they are not sufficiently effective because they do not completely adjust to the anatomy of the Animal. They are generic and need to be filled or tightened so that they do not strike.

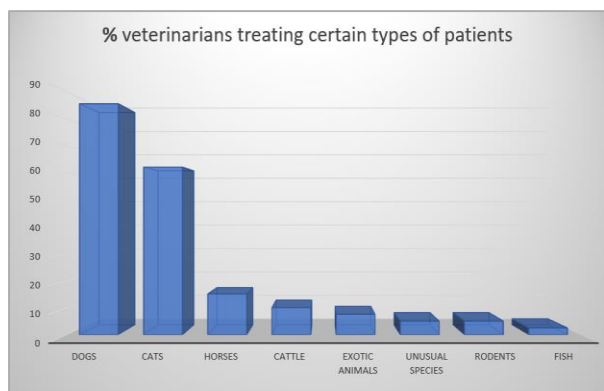
Other injuries are ligament ruptures; 21% pointed to them, mainly cruciate ligament ruptures.

Elbows and knees, in all their possible incidences, were also referred to, although in these cases, most of the injuries either require surgery or recovery therapy requires mobility so that only a small number of cases would require stabilization or temporary stabilization that is easy to remove, although it would be very helpful if the splint were easy to remove and reuse, here we are talking about 10.08% of incidence according to what we have been told.

#### *What Kind of Animals Do You Most Frequently Treat with this Type of Injury?*

Here, before referring to the numbers, we must understand an important detail. When we talk about treatment it does not imply that it is the animals that are injured but the animals that are cared for (Graph 5). Most of the rural veterinarians stressed that their patients are usually euthanized because the cost of treatment exceeds the value of the Animal's life.





**Graph 5:** Percentage of veterinarians treating certain types of patients

Urban veterinarians have also acknowledged that many animals are not cared for by professionals due to a lack of resources, especially less common species. Two groups stand out here, firstly those that are neglected or euthanized because they cannot afford the cost of treatment and secondly those that for the same reason or due to the lack of value of the Animal's life are cared for by non-professionals. This second group includes the vast majority of species whose value of life is more subjective.

For example, if a dog breaks a leg, the owner first tries to have it treated by a vet, if he cannot afford it, he tries to treat it with his own means and abandons it or euthanizes it as a third option. In the case of other types of pets, especially in less developed countries, the first option disappears and the pet owner tends to "cure" the Animal himself, doing splints and bandages at home.

Here again, the percentages will be in excess of 100% as many of the professionals deal more frequently with more than one type of Animal.

85.68% of the respondents said they treated dogs, 62.16% of the respondents' cats, 15% horses, and 10% bovines (Mostly breeding animals). 5.04% of the respondents admitted to eventually treating rodents, the same percentage to rare animals and almost 7.56% to exotic animals, something difficult to delimit since what is exotic for a veterinarian in Australia may not be so for one in Chile and vice versa, although in their environment they are exotic and, therefore, share certain problems.

Interestingly, one veterinarian said that he cared for all kinds of animals but had never cared for a fish, while 2.52% said that he occasionally did.

#### What Problems or Limitations Do You Find in The Stabilization Systems You Use?

On this question, the answers are unanimous. Around 80% agree on two things: They come off or loosen very frequently (82.32), which is accentuated by the fact that the patient does not understand that they should not try to remove them and that they generate chafing, dermatitis

and infections when they are closed (78.12), especially when they are not treated regularly.

Another item that stands out is cost, with approximately 40.32% mentioning it in their response to this question, although almost twice as many mention it in direct conversations or other responses.

21.84% said that the owners of the patients complained about the difficulty of maintenance during treatment.

#### What other Systems DO You Know of or Have Tried to Implement but do not Use, and Why?

30.26% of the respondents say that they have tried all the methods they have known, trying to find one that satisfies them sufficiently, but in general, they recognize that they have ended up using only the one that has given them the best result without continuing to opt for new alternatives.

Curiously, only 5 of the 119 (4.2%) mentioned the use of splints made by additive manufacturing, but none of them had had the opportunity to try them and they did not believe it was a short-term solution as they considered it a complex technology to implement, although they recognized that in the medium term it is very likely to be commonplace.

Some, 5.04% mentioned physiotherapy for soft tissue injuries or acupuncture, although they admitted not using them because they doubted their efficacy in animals due to the impossibility of keeping them still without stabilizing them during treatment.

15.96% said they never use rigid splints. The reason given was that, due to the lack of an adequate fit to the patient's anatomy, they must be tight to avoid looseness, which causes other types of setbacks and even injuries to the limb to be recovered.

#### What Feature Would You Improve on the Stabilization System You Currently Use?

A considerable number, 25.2% of the respondents either did not answer this question or were unable to suggest any improvements that they felt the equipment they use regularly might need. 7.56% considered, to some extent, that more important than improving existing devices is to change the mentality of the patients' owners.

41.16% acknowledged having a problem with the relationship between the solution to the lesion and water, many of them extending this to dirt in general. The difficulty in keeping the lesion dry and hygienic is, according to them, one of the biggest drawbacks unrelated to the treatment itself, which in some cases where there are open wounds, if the patients are not properly cared for, the consequences of the lack of hygiene can be more serious than those of the lesion.

Something that would not be expected in the case of medical devices, and not a few people highlighted it as a problem, specifically 23.52%, was that the materials they are made of often cause allergy problems. According to their comments, it is not uncommon to come across such

cases, and, as they reflect, either it is not something that worries manufacturers a great deal, or there is a real difficulty in avoiding these reactions.

In this question, approximately one-third or more of the professionals have referred to many issues concerning chafing. Specifically, 31.92% are dissatisfied with this. Chafing caused by splints and problems with the fit in general cause not only abrasions but even secondary injuries due to the need to tighten them excessively to keep them in place, sometimes due to excessive stiffness, sometimes due to the low-quality standards of some products.

36.12% said that standard splints are not easy to use as they come in a large generic size so that they can be used in the largest possible number of sizes, with the user having to adapt to the splint and not the other way around. Special mention was made of die-cut splints, which are not always easy to cut, and many of them end up breaking during the cutting process. Some of them do not even have dies, only marks indicating where the cut should be made, and in others, the dies are so deep that they tend to break during use due to lack of mechanical resistance.

35.28% acknowledge that, although they are in favour of JBB, they are cumbersome, slow and difficult to implement efficiently, especially if the patient is not sedated and that they tend to be easily disassembled. They believe that a device that offers a similar result but is easier to apply and guarantees that it will not come apart during use would be a major advance.

Almost 17.64% refer to the difficulties they usually encounter in the relationship between stabilization systems and post-surgical recovery equipment, as often, in order for surgery with surgical stabilizers to be successful; they also require the help of other elements either for secondary stabilization or to protect the wound or the surgical device. This is something that often presents difficulties and is often not used, not because it is not necessary, but because the harm is greater than the benefit (Graph 6).

#### *What is the Average Price of the Device You Usually Use, and What is the Average Price of the Other Equipment You Use for Regular Stabilization?*

The answers to this question, as might be expected, are very diverse.

The vast majority said it was very relative and depended on each case.

In the case of pets, in European countries, veterinarians caring for pets identified stabilization of a normal injury that does not require surgery at an average of €150 to €200, significantly more in the US, where the range is between €250 and €700.

In South American countries, we can identify a range between €20 and €40. In African countries, the range was wider, between €10 and €80 on average. Asia, on the other

hand, offered prices more similar to South America, between €25 and €50. In Oceania, Australia in particular, prices ranged between €350 and €500 on average.

When it comes to breeding or riding cattle, the average is between €350 and €700 in South American countries, €800 to €3000 in Europe and in countries such as Australia and the USA, it is in the range of €1500 to €5000, which shows that in this area it becomes prohibitive for certain groups. In Africa, from €400 to €1500, and in Asia, between €350 and €500 on average.

Excluded from this data are animals whose prices could be considered exorbitant, such as exclusive stallions or high-class thoroughbreds, as their treatments are proportional to their prices and are of no interest to our research and would distort the results.

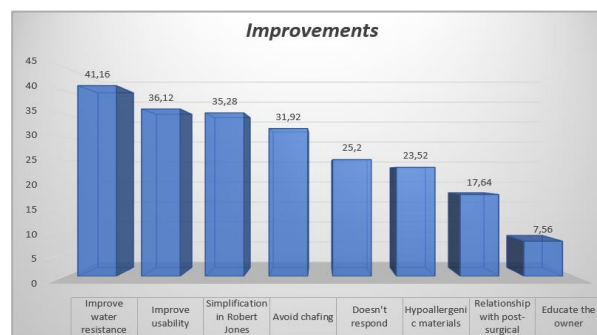
In conversation with some vets, they found that, as an example, in Europe a bag of good quality food costs around €25, a grooming session between €40 and €100, so if the stabilization of a fracture (Including sedation, x-rays, medical fees, etc.) costs €150 to €200, this study becomes comparatively inexpensive.

#### *Which Animals that You Routinely Treat cannot be Assisted with Standard Devices because they are Unavailable, Difficult to Acquire, or not Economically Justifiable?*

In response to this question, 20.16% of the respondents said that they only cater for a specific type of animals, so they have no problem with this, however, most of the rest (73.08%) acknowledged that they do not have devices to cater for small animals such as birds, ferrets, rodents, etc.

Interestingly, 34.44% say they do not have products suitable for assisting cats because they do not exist (According to 12.6%) or are not suitable for feline anatomy (According to 21.84%).

A high percentage of those working with livestock (More than 50%) say that they do not have anything to assist cattle, although none of them refer to other animals. We have raised this concern with some of them, and they have said that if a pig, goat, sheep, etc., has an injury, it is simply slaughtered or even abandoned.



**Graph 6:** Improvements that you would implement in the equipment you usually use

The case of equines is very different, as there are product options, although 76.44% of veterinarians comment that these devices are as if they did not exist because their prices are prohibitive.

### *How Often Do You Need to Improvise and Use Materials that are Not Specifically Designed to Stabilize Limbs or at Least Not for the Animal You are Assisting?*

When we talk about improvising, we mean and we have explained this to professionals, having to use elements that have not been specifically designed to stabilize bone injuries or that, even if they are, need to be significantly modified to be used properly (Graph 7).

In this situation, 10.08% said that they did not have to improvise with these devices. Returning to the answers to previous questions, all the members of this group coincide with those who had previously stated that they almost exclusively used JBB, which are not rigid devices but a method of bandaging, as we saw earlier.

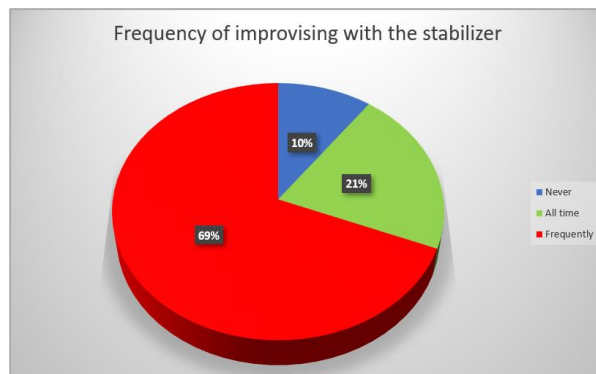
21% say that, although they use specific devices for the animals they are treating, they always need to improvise, as the splints always need to be adjusted so that the patient is stabilized in optimal conditions. The other 68.88% state that it is very common, and when asked how common this need is, on average, they put the incidence at between 60% and 70% of the time.

### *What kind of Animals are not Usually Stabilized in Case of Limb Injuries Still at the Mercy of their Injury? Why is this not Usually Done?*

In this section, the veterinarians distinguish between three groups.

Those that are usually not stabilized because there are no adequate means, those that are not stabilized because the means are not effective, and those that are not justified or have no resources to do so.

The world of pets has always been diverse, and although most are dogs or cats, many species are used as pets. Just because we are not used to seeing it, does not mean it does not happen. Most often, they are rodents or birds, but there are animals of all kinds, especially those smaller than humans. If we consider those that are most representative within this group, both rodents and birds, although they are usually stabilized with improvised resources, it is usual not to do so and to give them care so that they recover as they would in nature. Birds, due to their skeletal characteristics, usually have a fairly acceptable recovery, beyond the fact that they are very unlikely to suffer one. The rest of the species, although in developed countries it is more frequent that they are assisted, in the majority it is not, so the Animal must recover in a natural way. This is a very painful method for the patient, and the consequences are usually bad, even leading to death.



**Graph 7:** Frequency of improvising with the stabilizer

Among those who are not stabilized because the means are not effective are cats, which, although there are specific devices for them, are generally stabilized with the same or similar devices as dogs, firstly because it is not easy to obtain feline splints, secondly because as it is not common to treat them for poly traumatism these splints are comparatively very expensive, thirdly because even though they are specific, they are not effective due to the singularities of their anatomy which means that they end up losing their support (Even JBB). For this reason, many of these animals are not treated even if there are products that allow stabilization.

Finally, the group of those left unattended or euthanized represents a very high number of patients. Hundreds of thousands of pets die each year from such ailments after having been abandoned or home-cured.

Except for dogs, cats and horses (Only in some cases), most polytraumatized domestic animals are not treated, which is less common in wealthy countries. Beyond those animals that are cured without professional assistance, it is usual, or at least to be expected when it is considered that it is not possible to recover an animal from its injury, that they are euthanized to avoid suffering, but many are often abandoned to their fate, even if they are kept in the environment where they used to live.

Another important group of animals that are not usually stabilized, although in this case they are almost always euthanized, is geriatric patients, including dogs and cats, who are by far the animals most attached to their owners and for whom such a decision is usually the most traumatic.

Many other small reference groups could be identified, but basically, they point to similar situations, perhaps, as an interesting note, and since several professionals highlighted it, it is worth commenting on the case of horses (Those of great economic value), as they often receive extremely expensive treatment for various ailments, but a traumatic injury to the limbs can make them lose their value completely so that sometimes they are sacrificed even if they have every chance of recovering, although not to compete in the different disciplines and the owners have more than enough means to do so.



In extremity injuries requiring stabilization, what approximate percentage tend to have wounds that require healing during treatment and stabilization must be removed or hinder healing?

Here there is a curious gap in practitioner opinion, with no easy way to group trends between developed and less developed countries, or rural and urban veterinarians.

51.24% consider bone injuries accompanied by soft tissue injuries to be between 15 and 20% of animals in need of stabilization, wounds that should be treated regularly during treatment, while a group of almost 39.48% consider the frequency to be between 50 and 60%.

As we have explained, both geographical and typological dispersion do not allow us to define these two groups that have such divergent opinions.

The rest of the veterinarians consider that the number is not relevant or cannot be determined.

Do you know from experience or third-party referral that pets or livestock are often killed due to lack of care for limb injuries (Whether due to neglect, economic inconvenience, lack of knowledge, or lack of resources)?

All those consulted recognize that many pets are euthanized because of the difficulty for their owner to recover, not only financially but also because of the care required for the process. Some added that according to studies to which they have had timely access, these animals number hundreds of thousands each year in the case of polytrauma.

It is worth noting that there are some singularities in this issue. Veterinarians from more developed countries argue, especially those working in large cities, that it is rare, while those from other countries mostly consider it to be common, which is far from the term chosen in the survey that referred to frequent. These professionals considered that there is no taboo today in understanding that an animal that is not going to be treated should be euthanized and that it is very unlikely in certain sectors that animals are treated for injuries of this type. On the other hand, they make a clear distinction between dogs, cats, and other types of pets, considering that the first group is much less frequent than the second, where the frequency is remarkably close to the total.

In the case of livestock, all agree on the fact that, with very few exceptions, they are slaughtered or left to die.

Do you have any opinions or observations on the materials from which the stabilization systems are made?

Both those veterinarians working in developed countries who most commonly use expensive methods and those in places with fewer resources, almost all agreed that improvements are needed, in all cases in two areas. Hygiene and usability.

In relation to hygiene, they bring up again an issue they raised earlier: water resistance and ease of cleaning.

On the other hand, they stressed that it would be helpful to make them easier to install, easier to maintain, and more effective than a latent problem.

### *Do You have any General Comments on any of the Points or on the Topic in General?*

At this point, 12.6% of the respondents claimed, in one way or another, the importance of the veterinarian's experience, expertise or creativity in patient care, as not everything can depend on resources, given the enormous diversity in veterinary medicine and the lack of clear feedback from the patient.

On the other hand, 60.48% said that having the possibility of acquiring equipment for less common animals would be a very useful resource, while 68.4% highlighted the need for more modifiable splints to better adapt to the animals to be treated.

13.44% were interested in better educating new generations about the value of and respect for the life of a pet.

9.24% were concerned about the gap between more developed and less developed countries, which means that even though they have new solutions to do their work well, these solutions are not accessible in their environments.

### **Conclusion**

Before starting this research, it was evident that there were clear differences between professionals in different locations. However, this research allows us to narrow down these differences and measure them, giving us a key orientation to understand the context in which they work and the real resources available in the different locations and socioeconomic groups. Of course, a larger sample would allow us to reach more precise results, but the number is large enough and comes from sufficiently dispersed places to be able to consider credible and significant results from which we have obtained information.

From the observations of the professionals, we have extracted the parameters that define the context when making the necessary decisions for the next two phases of the project. This project, in its next phases, will develop devices from materials specifically designed for this use, taking into account the specific requirements and using the ideal technology that allows us to reach all parts of the world and with the requirements available in all those places. Obviously, since there is such a difference between users (not all places have 3D printers with the appropriate characteristics, not all places have CNC machining, etc.), the project must be adapted to the possibilities of each situation so that it is effective in all cases, something that, in the first tests that are already underway, has been achieved with amazing results.

### **Acknowledgment**

To the professionals who selflessly dedicated their time so that this project provides tangible solutions in the near future. To all the veterinarians who have selflessly participated in this research.

## Funding Information

Universitat Politècnica de València (CIF Q-4618002-B. camino de vera, s/n, CP. 46022 València) (payment for the publication of the article).

## Author's Contributions

**Marcelo Adrián Santamaría Brunengo:** Research and writing of the paper.

**Santiago Ferrándiz Bou:** Final approval of the version to be published.

## Ethics

An Ethics Committee Approval Letter is not required in this Project, Stabilisation of non-surgical polytrauma in animal limbs.

## Competing Interests

The authors declare that they have no competing interests.

## Declarations

The data and materials from this research are available for consultation or verification.

## References

- Bromiley, M. W. (2007). *Equine Injury, Therapy and Rehabilitation*.  
<https://doi.org/10.1002/9780470751206>
- DeCamp, C. E., Johnston, S. A., & Schaefer, S. L. (1983). *Brinker, Piermattei and Flo's Handbook of Small Animal Orthopedics and Fracture Repair*.
- David, L., & Millis, D. (2004). *Canine Rehabilitation and Physical Therapy*.
- Piermattei Donald, L., & Greeley, R. G. (1996). *An Atlas of Surgical Approaches to the Bones of the Dog and Cat*.
- Li, J., & Tanaka, H. (2018). Rapid Customization System for 3D-Printed Plint Using Programmable Modeling Technique – A Practical Approach. *3D Printing in Medicine*, 4(1), 1–21.  
<https://doi.org/10.1186/s41205-018-0027-6>
- Marcus, W. (2012). *Veterinary Medicine in the Third world, Challenges and Projections*.
- María, C. T. J., & Julián, R. F. (2016). *Manual De Suturas en Veterinaria*.
- Morgan, P., & Esther, C. (2019). *Animal Injuries. Technical Resources and Possibilities Beyond Orthopedics*.
- Son, J., Herrera Valenzuela, D. S., Sacristán Gutiérrez, M. C., & Vargas Castellanos, P. M. (2018). Una Actualización Sobre Aplicaciones Ortopédicas Usando Tecnologías de Impresión Tridimensional. *Revista Ingeniería Biomédica*, 12(23), 45–51.  
<https://doi.org/10.24050/19099762.n23.2018.1079>
- Wright, I. (2022). *Fractures in the Horse*.  
<https://doi.org/10.1002/9781119431749>
- Zaera, J. (2022). *Traumatología en Pequeños Animales. Resolución de las Fracturas más Frecuentes*.
- Zolfagharian, A., M. Gregory, T., Bodaghi, M., Gharaie, S., & Fay, P. (2024). Patient-Specific 3D-Printed Splint for Mallet Finger Injury. *International Journal of Bioprinting*, 6(2), 259.  
<https://doi.org/10.18063/ijb.v6i2.259>