Difference in Toe And Heel Angles

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A thesis examining the suggestion that toe and heel angles can never be equal as stated in many textbooks

Contents

Introduction

It is clearly believed that the current theory regarding the relationship between the angles of the horse's dorsal wall should, ideally, be parallel with the angle of the heel buttresses:

"The angle of the heel should correspond to the angle of the toe." (Lameness in Horses, Adams)

"The quarters are symmetrical and the heels from the buttress to the bulbs form an angle similar to that at the toe. (The Principles of Horseshoeing. II, Butler.)

"The angle of the hoof at the heel should be parallel to the angle at the toe. When the heel angle is 5° less than the toe angle, the hoof is said to have under-run heels." (Horse Owner's Guide to Lameness. Ted Stashak, 1996)

Textbooks tell us that the dorsal wall and buttress should be parallel on an ideal foot (See Fig. 1 below). This theory is reinforced when the tubules of the hoof are examined; they are seen to be parallel (See Fig. 2 below), and we are told that they are 'cemented' together with intertubular horn so they must remain parallel.

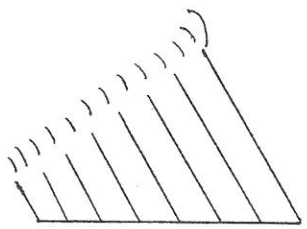


Fig 1

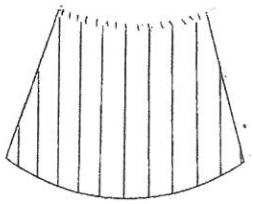


Fig 2

The author believes that this is only possible when the foot is seen as a section of a cylinder (See Fig. 3), which, in reality is very rarely the case. When the hoof capsule is viewed from the front, it is clearly seen to be a conical shape.

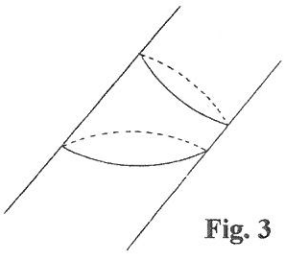


Fig. 3

This paper will therefore test the hypothesis that it is impossible to obtain equal angles of both the dorsal wall and the heel buttresses in the equine foot if the horn tubules and/or laminae are arranged in parallel in a healthy hoof wall. The author expects the only possible exception to this hypothesis to be the hoof of a donkey, due to the fact that the medial and lateral walls are practically parallel to each other and are therefore not conical, but almost cylindrical.

This investigation will measure the angles on horses' feet that have good conformation to see if the textbooks are correct. It will also measure the feet of horses that have less than ideal conformation. This will show whether any correlation exists between the toe and heel angles of an equine hoof with good conformation and also one with an angle of less than 50°.

The author expects the results to show that horses with feet close to an 'ideal' conformation will show a relatively small difference in toe and heel angles, whereas the 'flatter' feet will show a relatively large difference between toe and heel angles.

It is therefore proposed that it is impossible to draw parallel lines on a structure that is fundamentally cone shaped and also keep the angles equal. One or the other can be done, but not both.

The Structure of the Horse's Hoof Capsule

One of the few facts that could alter the validity of this study is the arrangement of the horn tubules. If they were shown to be diverging towards the distal aspect of the foot, then this fact alone would change the credibility of the argument put forward in this paper. Three facts appear to uphold the position held in this study.

1. On every foot studied the tubules can be seen to be parallel very clearly. On some feet with badly under-run heels, the tubules may bend and run forward, but still remain parallel.

2. When the anatomy of the hoof wall is considered then it becomes more evident. The wall is a modified epithelium, and is composed of keratinised epithelial cells that are solidly cemented together with keratin. These specialised cells are arranged in tubules formed by the coronary band. The coronary body that sits in the coronary groove is covered by the coronary corium that is covered by tiny papillae. Each papilla secretes one horn tubule made from tubular horn and intra tubular horn. The tubular horn gives the wall its strength and structure, and the intra tubular horn acts as a moisture conveyor. The coronary corium between each of the papillae secretes inter tubular horn to cement each tubule to its neighbour as it travels down the wall. This incredibly strong arrangement endows the hoof with its toughness and ensures that the tubules stay parallel within the wall.

3. A morbid specimen of a foot with the distal phalanx removed shows the arrangement of the horny laminae of the hoof wall. Two aspects can be observed. Firstly, that they travel down the wall in parallel lines, and secondly that they display a very different angle at the heel compared to those at the toe.

Materials and Methods

Result Collection

For the theory suggested in this paper to be proved, a reliable method of measuring the angle of both the dorsal wall and the buttress had to be designed and employed. This was not as easy as was first thought. Several methods were tested, involving various measuring devices of different designs.

Calculating the angle of the dorsal wall was relatively easy and a regular hoof angle gauge could be used successfully, providing the hoof capsule had been prepared with a straight line from coronary band to ground surface and a relatively flat solar surface (Method shown below in Fig. 4). The problems associated with measuring the angle of the heel buttresses were quite different. The concern was that with some very flat feet it was difficult to obtain a definitive line because of the extent of the under-run heels. Following several experiments it was decided that the most accurate and reliable method was to take digital photographs of the feet and read the angle from these. The camera was always placed at ground level and midway between toe and heel (Method shown below in Fig. 5). The method of photographing all feet also allowed a permanent record of all feet to be kept and the results from the hoof gauge to be checked by a second means.

Fig. 4

Measuring toe angle using traditional hoof gauge.

Fig. 5

Capturing angles with digital camera

To illustrate the way in which the results were obtained, a sample photograph is shown below (Fig. 6). To allow the angles to be calculated, lines have been drawn following the horn tubules near the buttress (as they are clearly indicated by the change in pigmentation), the angle of the toe, and the level plane on which the foot is photographed.

Fig. 6

Strong foot with different pigmentation showing different angles

As is clear from the above illustration, sometimes lines were drawn on feet at different points than the heel. This was usually because the feet had different pigmentation and so a line could be drawn very accurately on the image following the line of the different coloured horn tubules. This method was employed because the study assumes the angles change more as they are measured further towards the heel then this would not influence the results in an adverse manner. As is clear from the illustration, the angle of the toe is 50°and the angle of the horn tubule situated at the heel quarter is 40°, showing a clear difference of 10°.

Once the results had been collected and checked, they were entered onto a graph, allowing the data to be viewed on a clear format. This enabled the author to compare the results easily and in a constructive manner.

One of the aspects of the study that was considered to be important was that if the angle at the toe differed from that at the heel, several questions needed to be answered:

- Would there be a constant difference in all feet?
- Would the study show a greater difference in flat feet than in a stronger pony type foot?
- Would a donkey show any difference at all considering that they are almost tubular in shape with very little discrepancy between measurements around the coronary band compared to the measurement around the ground surface of the foot, heel to heel?
- What implications may the study hold for farriers?

Problems did arise because some of the hooves with very low angles proved to be very difficult or even impossible to measure the heels with any accuracy. This was due to the fact that as the horn tubules run forward at the heel and become crushed it is extremely difficult to draw a line with any confidence on the digital photographs. In all these cases it was decided to draw a line at the most caudal point on the foot that showed the angle of the horn tubules clearly.

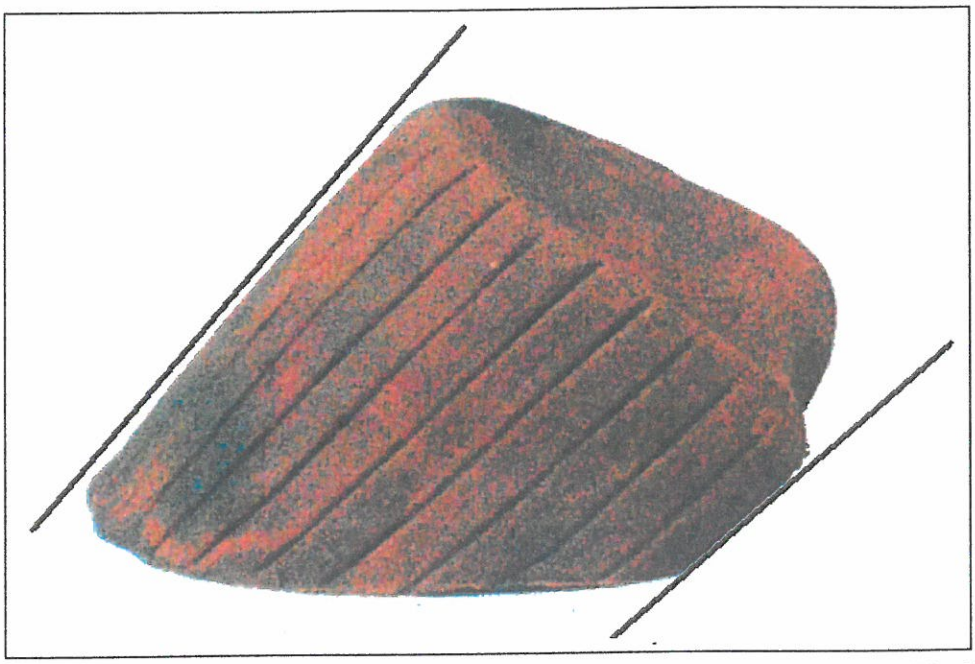
Foot Dressing Techniques

One aspect that was most important right from the beginning was to keep inaccurate measurements to an absolute minimum. The most obvious one being that the angle of the dorsal wall could be manipulated on certain feet by rasping high up almost to the coronary band and then creating the desired angle .This would show a steeper angle at the toe and therefore put credibility of the study in question. This was overcome by only rasping flares away, and even then keeping that to a minimum. The top third of the hoof capsule was used as the true angle because in most cases this is parallel to the parietal surface of the distal phalanx within.
It also occurred to the author that the angle the buttress makes with the ground varies depending on how the ground surface of the foot is trimmed, but as long as it is trimmed flat then it will change the angle of the dorsal wall by the same amount as the heel. Since the main importance to this study is the fact that there is a difference and not so much the extent of the difference, then this was considered unimportant.

Models Made and Used

The statement that the horn tubules stay parallel to each other, and yet are a different angle at the toe and heel, sounds both contradictory and impossible, which it most certainly is in two dimensions. This phenomenon is quite difficult to appreciate until a three-dimensional model is made, when it becomes very evident.

A realistically shaped hoof capsule was made from plasticine (Fig. 7 Below). Parallel lines were made on the dorsal surface and it was soon evident that it was not possible to make the lines parallel and maintain the same angle with the ground. Numerous models were made with varying hoof angles, the hooves with the lowest angles showing the greatest difference in angle between the toe and the heel. Either the lines must diverge as they travel down the wall or they must change their angle towards the heel.



Plasticine model **Fig. 7**

A second design of model was created to try to explain exactly what was happening as the hoof shape changed. This time the model was made from wood in the form of a donkey's foot i.e. medial and lateral walls parallel (Figs 8b & 8c). This was covered in a moveable outer skin made from flexible plastic (Fig 8a). Before it was wrapped around the model hoof shape, parallel lines were drawn on it to simulate horn tubules. The lines were measured at 5mm intervals to ensure that they were parallel. The plastic was fixed at the dorsal wall and at the coronary band for the front half of the foot. The idea behind this model was to see what would happen to the moveable heels if the sides of the plastic covering were pulled out to simulate a flared foot shape instead of the tubular wooden shape. Angles were measured while the medial and lateral walls were parallel. These were almost equal at 52° (toe) and 53°(heel). Then the shape was changed by inserting blue tack at the quarters to simulate a more

realistic foot shape of a horse (fig 9). Two things occurred, one expected and one not. As the hoof became flared, something had to move, in order to accommodate the change in shape. This mainly came from the heels being pulled forward as expected, but the second thing that happened was that the coronary band was also dragged down at the heels, giving the shape of the coronary band that most farriers would recognise as a sign of a hoof with under-run heels. Measurements were taken again and even though the toe angle was obviously still the same, the heels had been pulled forward to 45°. This being a difference of 7° on a shape that most farriers would consider to be strong and upright even though most books would state that this degree of variation suggests under-run heels. Therefore, the plastic covering which had parallel lines drawn onto it showed different angles, caudal and dorsal, when applied to a foot shape. This concept sounds contradictory. How can the two angles be different when each line is parallel to its neighbour? Surely the angle of each line must remain at 52°. It does as long as they are drawn on a section of a cylinder but they physically have to change to accommodate any flaring of a foot.

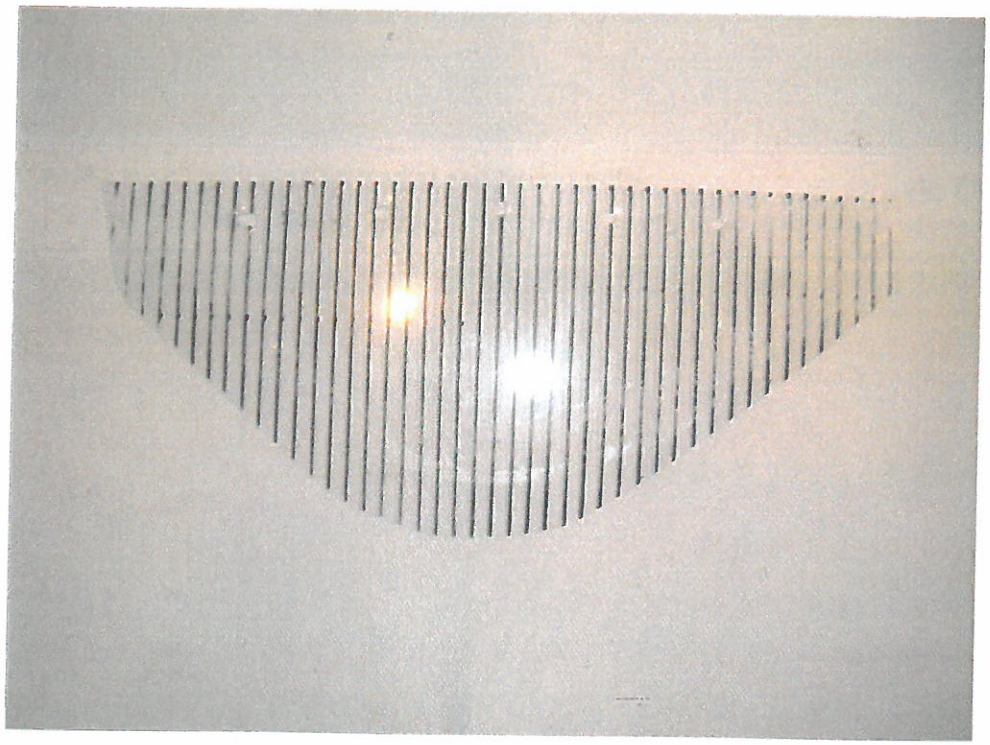
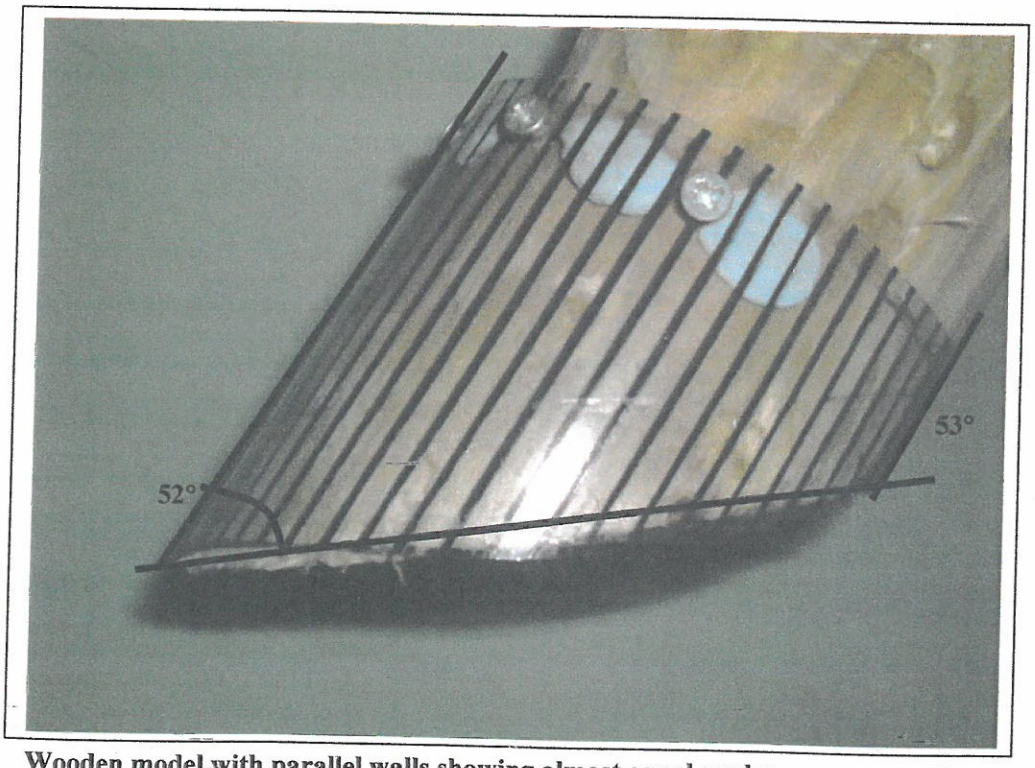


Fig.8a

Plastic sheet with parallel lines before wrapping around the wooden model

Wooden model with parallel medial and lateral walls **Fig. 8b**



Wooden model with parallel walls showing almost equal angles

Fig. 8c

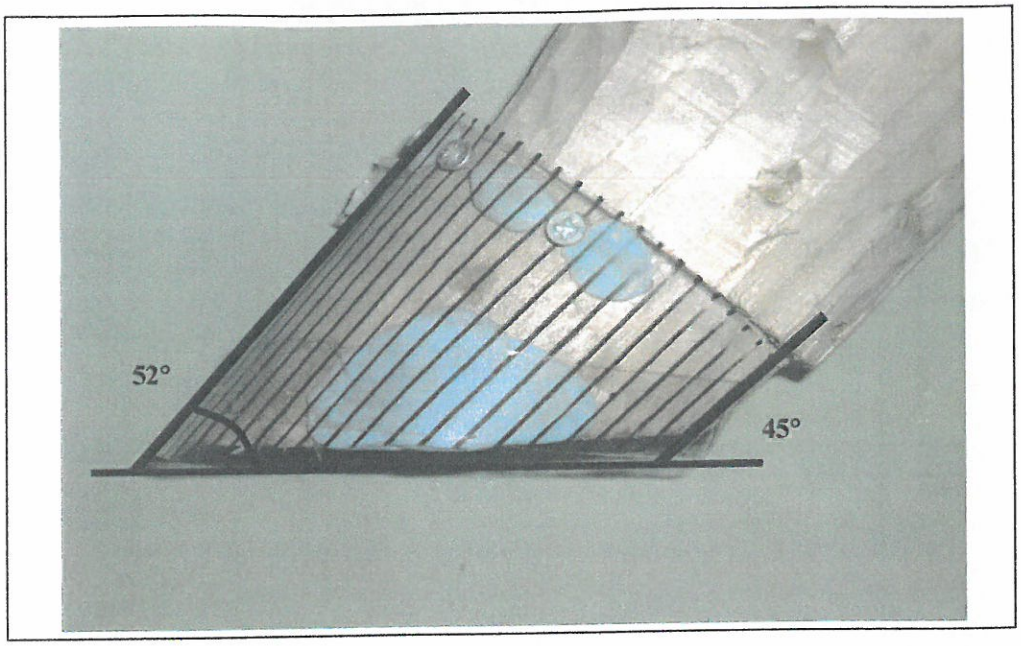


Fig. 9

Wooden model with flared quarters showing different angles

A morbid specimen of a horny hoof capsule with the pedal bone removed was studied and an interesting observation was made: All the horny laminae can be seen on the inside of the capsule in great detail. They are quite definitely parallel to one another, but at the same time they are at a much lower angle at the heel than the toe (Fig. 10 below).

Fig. 10

Morbid specimen showing changing angles of horny laminae

Results

The table below shows the difference in angles of all the front feet measured in the study. They vary from very flat feet at the top of the table, to the very upright feet of the donkey. The main bulk of results are in the range 50 to 57, usually considered to be 'normal'.

Horse	Toe Angle	Heel Angle	Angle Difference	Percentage Difference
Flight	45	30	15	33.3
Senny right front	46	31	15	32.6
Chaz front	47	26	21	44.7
Henry front	48	33	15	31.3
Max front	49	34	15	30.6
Eddie front	49	44	5	10.2
Senny left front	49	23	26	53.1
BJ	50	43	7	14.0
Sly, Left Front	50	49	1	2.0
Dr. A	50	39	11	22.0
Sid	50	39	11	22.0
George	50	32	18	36.0
Sparky	51	34	17	33.3
Polly	51	43	8	15.7
Sly, Right Front	52	38	14	26.9
Betty	52	34	18	34.6
Taz	52	45	7	13.5
Chaz	52	38	14	26.9
Sid	52	35	17	32.7
Maddie	53	43	10	18.9
Charlie	53	35	18	34.0
Francis	53	39	14	26.4
Harry	53	40	13	24.5
Austin	54	39	15	27.8
Bay Mare	55	38	17	30.9
Molly	55	43	12	21.8
Cob	55	47	8	14.5
Hannah	57	43	14	24.6
Donkey	69	69	0	0.0

Table of measurements of toe and heel angles of hind feet.

Horse	Toe Angle	Heel Angle	Angle Difference	Percentage Difference
Henry right hind	44	33	11	25.0
Henry left hind	48	31	17	35.4
Max hind	49	29	20	40.8
Chaz hind	49	35	14	28.6
Eddie hind	49	32	17	34.7
Harry	50	35	15	30.0
Missy	52	41	11	21.2
Gent	52	43	9	17.3
Yearling	52	49	3	5.8
Tracy	52	35	17	32.7
Staff	53	36	17	32.1
Sid	54	32	22	40.7

Analysis of Results

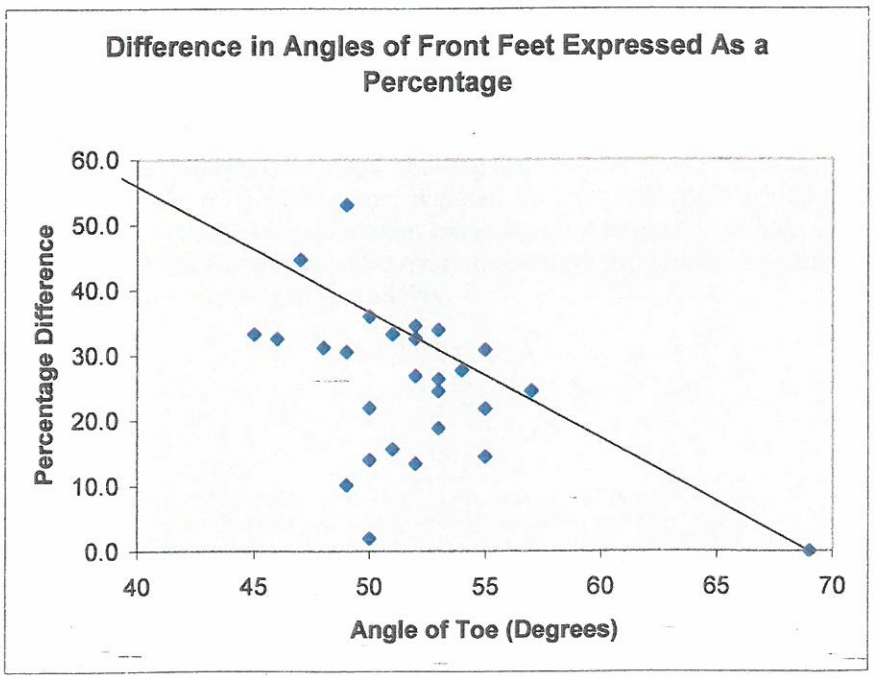
When analysing the results that have been collected several main observations can be made:

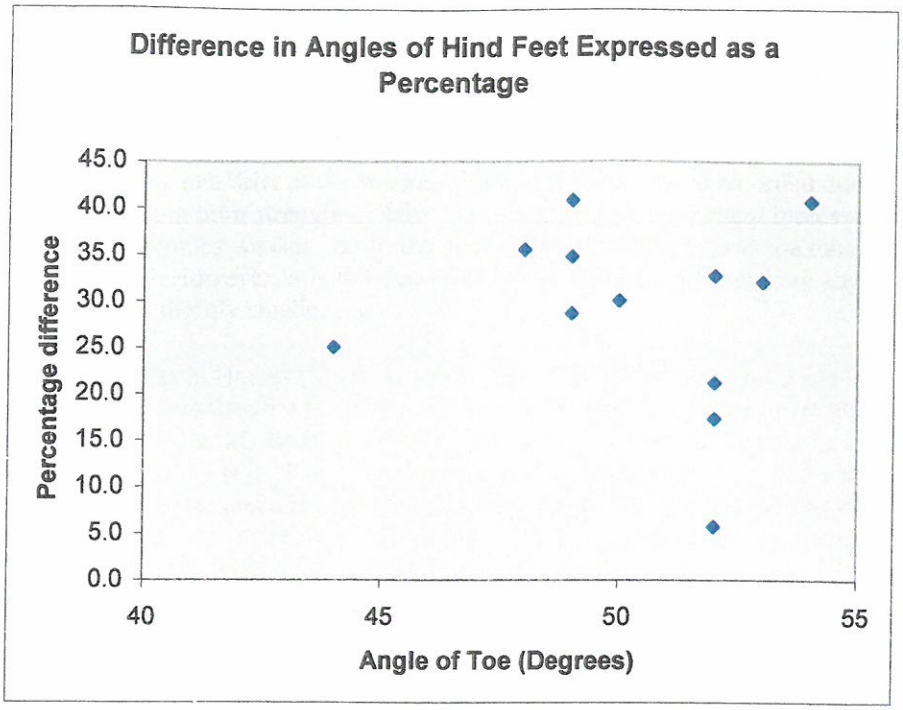
1. There is a conclusive difference between the angle of the dorsal wall and that of the heel.
   - Every horse's foot studied showed a difference of angle, and with over 40 horses studied this provides sufficient evidence.

2. The angle at the heel did not vary proportionately with the difference in angle at the toe. That is to say, that as the toe angle gradually becomes less, the heel angle does not necessarily vary by the same proportion.

3. The exception to the above observations is the donkey foot.

The results of the main study were very conclusive and indeed there was not a single horse's foot measured that showed equal toe and heel angles. However, the expected difference in angles as the feet became flatter did not seem to hold true. This may have been partly due to the fact that it was extremely difficult to find an accurate method of measuring the very flat feet, with under run heels. This was mainly due to the fact that the angle of the buttress changes as it runs forward on these sorts of feet. Even though there was no true correlation showing that the percentage difference increased as the angle became lower, one aspect that was noted from the results was that the very flat feet did usually have the biggest disparity.
The difficulty of obtaining an exact measurement of the heel angle on these flat feet was not really a problem because the study only set out to prove whether or not there is a difference and not how much of a difference. Because these feet always have different angles, the only question is by how much do they differ?





It was decided to measure the toe and heel angles of hind feet as well as fronts to see if there was any disparity between the two sets of results. As can be seen from the table both sets of results are very similar with a similar spread of variation as the fronts. This was to be expected due to the fact that the medial and lateral walls of hind feet are not parallel either.

It was expected that the results would show that the flatter feet would exhibit a bigger difference in angles than the stronger feet but as discussed earlier this was not the case. If that assumption had held true, then the main bulk of the results would show a line as demonstrated on the first graph. Whereas, in reality the graph displays a random spread of results so that no trend can really be seen at all. The only concrete fact to be taken from the graphs is that every foot except the donkey does show some difference between the toe and heel angles.

Discussion

There are certain observations that warrant further discussion:

- One variable that may have had an effect on the study is that all the horses measured live in an area of very high rainfall. This obviously means that a lot of the feet have a high moisture content even in the summer. If the same study was done in a drier environment, different results may be recorded due to the increase in horn strength of drier feet. As the moisture content increases, the horn becomes weaker and so the hoof angles may be lower as the tubules run forward. However, it is felt that there would still be a difference in angle, albeit a slightly smaller one.

- Lameness in Horses (Stashak, 1996) states that 'When the heel angle is five degrees less than the toe angle, the hoof is said to have under run heels'. Results from this study show convincingly that this is not the case as is clearly shown below (Fig. 12). This picture shows a strong pony foot with a toe angle of 54 degrees and a heel angle of 38 degrees, and despite the difference in angles, it was clear when the foot was trimmed that the heels were strong and healthy and most definitely not running forward.

Strong pony foot showing different angles **Fig. 12**

This foot shows a difference of 16 degrees and this leads the author to question if a definitive number of degrees difference can be applied to under run heels.

This is an example of a strong hind foot, with a toe angle of 53 degrees and heel angle of 36 degrees. This is a difference of 17 degrees and according to all textbooks these heels should be seriously under run. It is also noted that the lines of pigmentation prove that the toe angle has not been altered artificially and also allowed easy measurement of the heel angle.

Pony foot with different pigmentation **Fig. 13**

- An anatomical fact that may allow heels to pull forward to accommodate the flared foot shape of the quarters is that the distal phalanx is located in the front 80% of the capsule and does not extend right into the heels.

- If the coronary band of an average foot is measured from the buttress of one heel, around the front of the foot to the buttress of the other heel it may measure about ten inches. If the same foot is measured from the point of heel, around the ground surface to the point of the other heel, it may measure about twelve inches. If the coronary band is connected to the ground surface by a series of parallel tubules, how can the measurements vary by 20%?

- Some readers may be concerned that there is room for misinterpretation of heel angle measurement due to the fact that it is sometimes difficult to determine the exact angle from the digital photographs. Although certain difficulties did occur in measuring heel angles on feet with a toe angle less than 50 degrees, this was considered to be irrelevant because the percentage difference was so high that the only concern was not whether the heel and toe angles were different, but by how much they differed.

- Below is a picture of a donkey foot (Fig. 14). It is immediately seen that the toe and heel angles are virtually equal and do indeed measure the same at 68 degrees. This is believed to occur because when viewed from the front, there is no flare to the foot, which pulls the heels forward (i.e. the foot is cylindrical)

Donkey foot with parallel heel and toe

Fig. 14

Implications for Future Farriers

During this study, the author has noted several anomalies in current thinking regarding the hoof capsule and how it affects movement and gait of the horse:

1. Horses with very weak, flat feet, usually have lower foot angles in hind feet than the front feet.
2. Toe and heel angles can vary by as much as 15° and the foot would not necessarily have under-run heels.
3. It should not be considered desirable to attempt to manipulate the angles to appear equal.

Conclusion

The overwhelming results provided from measuring over 40 horses show that it is sensible to state that if the horn tubules of the horny wall of the horse's foot are parallel, it is not physically possible for the dorsal wall angle to be parallel with that of the heels.

It has been proved that both strong and healthy feet and the poorer, weaker feet can and obviously do, function without the angles being the same. The author not only believes this but also believes that it would be undesirable to try to manipulate the angles to the extent that they become parallel. Doing so would most probably be detrimental to the foot.

Following this investigation, the author would like to see the current thinking and understanding of the anatomy of the horse's foot to be seen in a slightly different light, with more attention being paid to the living, everyday horse and not the horse that exists in textbooks alone. The study lends itself to further research and trials to see if the results differ under different conditions. The fact that the two angles can never be the same will never change, but the percentage difference between them may vary with differing horn quality and stronger hoof capsules. I would like to think that not only people starting out in our profession, but also experienced farriers out in the field will take on board these ideas and observe horses' feet for themselves. With an open mind and being receptive to new findings, we can make ourselves even better at the job that we all enjoy so much.

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