Measuring the Specific Gravity of Urine of Dogs Using Digital Refractometers

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Abstract

In veterinary medicine, urine specific gravity (USG) is among the most commonly used indicators of renal function, typically assessed by means of manual refractometers. However, accurate readings require a trained eye and adequate lighting conditions, limiting their use outside of clinical settings. This study investigates whether digital refractometers can serve as a reliable alternative, and in particular whether pet owners are able to use them independently for continuous at-home monitoring of their animal's USG. With a mean deviation of 0.0014 ± 0.0008 between devices, the results demonstrate that digital refractometers yield measurements comparable to those of manual devices, paving the way for broader at-home use by pet owners.

1 Introduction

Urine specific gravity (USG) is a key indicator of renal function in animals [5] and is routinely measured using manual refractometers in clinical settings. However, accurate readings require a trained eye and adequate lighting conditions, limiting their use outside of clinical environments. Furthermore, readings are susceptible to observer bias: studies have shown that results are interpreted differently by multiple veterinarians when using manual refractometers [3, 4], leading to discrepancies that can influence clinical assessment [5]. To address these limitations, digital refractometers offer a compelling alternative, providing objective and unambiguous readings [1]. In particular, we aim to enable at-home testing by pet owners, which offers two key benefits: first, by staying in a familiar environment, stress for animal patients can be reduced; second, a denser test frequency can be ensured without increasing costs.

However, to date there has been only limited interest in evaluating the accuracy of digital refractometers. For instance, [4] compared manual and digital refractometers using urine from 38 dogs and demonstrated high measurement reliability observed across measurements. Nevertheless, the level of training and experience of the operator was identified as an important factor in achieving reproducible results, which raises concerns about the suitability of manual refractometers for use by untrained laypersons. Similarly, [1] compared the degree of agreement between manual and digital refractometers using urine from 55 cats, with all measurements performed by a single operator to minimize variability. The results revealed a a small statistically difference; however, values obtained with the manual refractometer were consistently higher than those obtained with the digital device, indicating a systematic device bias. In contrast, in [5], where four different refractometers (including a digital one), were compared, the tested refractometers yielded slightly different results, however, presumed to be not clinically relevant.

These studies show, on the one hand, that there is no clear evidence that manual and digital refractometers consistently yield comparable results. On the other hand, they highlight the importance of

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device calibration, operator training, and consistent device use. Our aim, however, is to enable pet owners to continuously monitor their animal's USG using a digital refractometer independently at home. For this purpose, we employ a modern, easy-to-use digital refractometer and compare the measurements with those of a calibrated, standardized manual refractometer. The results demonstrate that the two devices yield comparable measurements, paving the way for further studies and broader clinical application. The rest of the paper is organized as follows: First, in Sec. 2, we give an overview of the devices used. Then, in Sec. 3, we describe the experimental setup and discuss the obtained results. Finally, in Sec. 4, we summarize and conclude the paper.

2 Manual and Digital Refractometers

To measure the specific gravity of urine, we compare a calibrated manual refractometer and a modern digital refractometer (SmartRef[1]), tested by veterinarians and pet owners.

2.1 Manuel Refractometer

A manual refractometer, as shown in Figure 1, measures the refractive index of a liquid sample – that is, the degree to which light bends as it passes through the sample – and converts this into a readable scale. In veterinary use, a drop of urine is placed onto the prism and the cover is closed [2], causing the urine to spread evenly across the prism surface. The refractometer is then held up to a light source, and the USG value is read at the boundary between the light and dark fields on the internal scale, see Figure 2. The reading therefore depends on adequate lighting and the observer's ability to correctly interpret this boundary line. The thus obtained data must be entered into the patients record and can then be analyzed in an additional step. To ensure a robust measurement, the manual refractometer was cleaned by wiping it with a clean soft paper towel.

Figure 1: Manual refractometer.

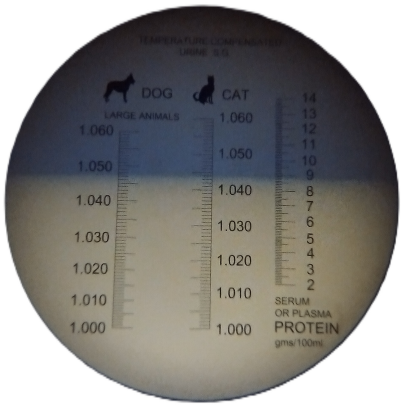

Figure 2: USG measurement value to three decimal places.

2.2 Digital Refractometer

In addition to the manual refractometer, we use the digital refractometer SmartRef (see Fig. 3). The device is accompanied by a range of apps designed for various liquids such as juices, beer, wine, or vehicle coolants (see Fig. 4). In our case, we used the app *Pet Care Meister*, which allows us to measure the specific gravity of urine and the sugar value in the urine of dogs, cats, and large animals.

[1]The company Anton Paar was neither a client nor involved in the study at all.

Figure 3: SmartRef.

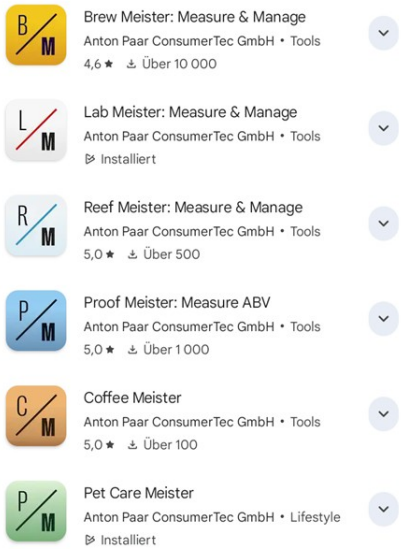

Figure 4: SmartRef apps.

Before measurements, the device must be paired with a smartphone via Bluetooth and calibrated with distilled or tap water. For cleaning between different urine samples, the sample well was sprayed with 90 % ethanol and wiped dry with a clean soft paper towel. For the actual measurement, 0.4 ml of urine is pipetted into the sample well using a disposable pipette or syringe. The measurement is then initiated via the smartphone app by pressing the Start button; the result s displayed within one second. The device supports both individual (see Fig. 5) and continuous measurements. The USG measurements can be saved and displayed as a curve, as shown in Figure 6. The x-axis represents the date on which the measurement was saved, the left y-axis shows the USG values, and the right y-axis shows the ambient temperature. The USG values are displayed in blue, and the temperature values in red.

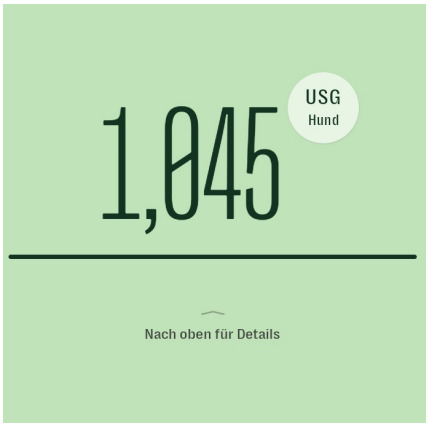

Figure 5: Detailed information on a single measured value.

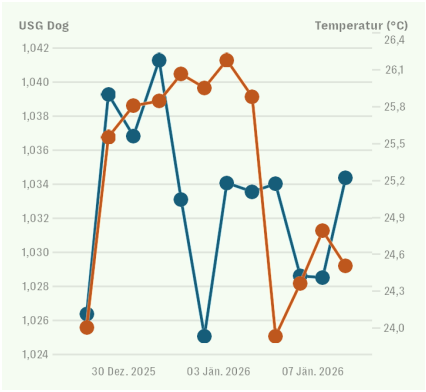

Figure 6: Plots of multiple measured values: USG (blue), ambient temperature (red).

To integrate the animals's values into the attending veterinarian's patient records, they can be exported as Comma-Separated-Values (CSV) file, and sent via email, for example, as illustrated in Table 1.

Table 1: The table shows the exported values from the SmartRef app.

Animal ID	Date	Time	Type	Temp.	Unit	Value	Univ	pH-Value
Dog-01	28/12/2025	11:06:12	—	24.0	°C	1.026	USG Dog	—
Dog-01	29/12/2025	09:08:19	—	25.6	°C	1.039	USG Dog	—
Dog-01	30/12/2025	10:38:26	—	25.8	°C	1.037	USG Dog	—
Dog-01	31/12/2025	12:43:10	—	25.8	°C	1.041	USG Dog	—
Dog-01	01/01/2026	11:03:44	—	26.1	°C	1.033	USG Dog	—
Dog-01	02/01/2026	10:42:19	—	26.0	°C	1.025	USG Dog	—
Dog-01	03/01/2026	09:26:01	—	26.2	°C	1.034	USG Dog	—
Dog-01	04/01/2026	11:10:52	—	25.9	°C	1.034	USG Dog	—
Dog-01	05/01/2026	10:55:24	—	23.9	°C	1.034	USG Dog	—
Dog-01	06/01/2026	11:59:52	—	24.4	°C	1.029	USG Dog	—
Dog-01	07/01/2026	10:43:28	—	24.8	°C	1.029	USG Dog	—
Dog-01	08/01/2026	10:02:15	—	24.5	°C	1.034	USG Dog	—

3 Evaluation

Volunteer veterinarians and pet owners collected urine from the animals and carried out the measurements. In the following, we describe the urine collection process and provide an overview of the results obtained.

3.1 Urine Collection

Spontaneous urine was used for the measurements, collected by free-catch method using two different collection aids. Commercial collection bowls, such as those by Himiyer (see Fig. 8), are available in two sizes and suitable for most dogs. However, they are less suitable for female dogs that lower their pelvis close to the ground when urinating (Fig. 7), and some female dogs refused to urinate when the bowl was present. To collect urine from these animals as well, we created a custom adapted collection device using 3D printing (see Fig. 9).

Figure 7: Female dog urinating: the pelvis is pressed low towards the ground.

Figure 8: Urine collection aid: Himiyer.

Figure 9: Urine collection aid: 3-D print.

Both collection aids feature a telescopic rod, allowing the collection bowl to be positioned under the urine stream with minimal effort. To transfer the urine to the refractometer, the required amount is drawn up from the collection bowl using a disposable pipette or syringe: 0.4 ml for the digital refractometer, or a single drop for the manual refractometer, applied directly onto the prism.

3.2 Comparison

Urine was collected from 13 dogs in order to measure the specific gravity and glucose levels using both the manual and the digital refractometer. The thus obtained results are summarized in Table 2, showing only a maximal difference of 0.002 between the SmartRef and the manual refractometer, which is within the measurement tolerance.

Table 2: Comparison of the measured values of a SmartRef and a manual refractometer.

Animal ID	SmartRef		manual
	USG	Brix / sugar	USG
Dog-01	1.026	6.7	1.026
Dog-02	1.012	2.8	1.013
Dog-03	1.025	6.3	1.026
Dog-04	1.047	12.5	1.049
Dog-05	1.032	8.3	1.034
Dog-06	1.023	5.7	1.024
Dog-07	1.016	4.0	1.018
Dog-08	1.060	16.2	1.060
Dog-09	1.020	5.1	1.022
Dog-10	1.034	8.9	1.036
Dog-11	1.050	13.2	1.051
Dog-12	1.019	4.7	1.021
Dog-13	1.045	11.9	1.047

4 Conclusion

The results demonstrate that digital refractometers yield measurements comparable to those of manual devices. At-home testing offers two key advantages: it reduces stress for animal patients by allowing measurements to be taken in a familiar environment, and it enables a denser monitoring frequency without increasing costs. These findings support the use of digital refractometers by trained pet owners and provide a basis for further studies involving additional species, including livestock, cats, and zoo animals.

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