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Performance evaluation of a new and improved cuvette-based automated urinalysis analyzer with phase contrast microscopy

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ABSTRACT

Background: The use of phase contrast in urinalysis has been highly recommended. A new system, sediMAX conTRUST PRO, is now available providing simultaneous automated phase contrast and bright field microscopy. This study aimed to evaluate both analytical and diagnostic performance of this new analyzer.
Methods: Results from 504 samples evaluated with the sediMAX conTRUST PRO were compared to those obtained from the same samples by manual microscopy (MM). Analytical and diagnostic performance were assessed according to established guidelines.
Results: The concentration of red blood cells (RBCs)and white blood cells (WBCs) at which the LoQ satisfied a CV < 25% was 12 particles per µL (p/µL) and 8 p/µL, respectively. Within one grade of agreement concordance was quite high, 97.8% for RBCs and 98.0% for WBCs, and above 90% for all other particles. Overall, diagnostic sensitivity and specificity were good (> 80%) for the particles considered, although lower sensitivities, 70.6% and 61.8%, were respectively found for hyaline and pathological casts.
Conclusions: The sediMAX conTRUST PRO provides very good performance in terms of RBC and WBC recognition and enumeration, and quite good performance for all other particles. Hyaline cast and pathological cast identification is fine and comparable to other automated systems, but could use further improvement.

1. Introduction

Urinalysis is one of the oldest yet essential tests performed for the evaluation of patients with kidney and urinary tract diseases. The onset of urine sediment analysis automation in the 1980s [1] has facilitated screening for impaired kidney function by increasing productivity and reducing observer-associated variability. In 2007 the precursor, sediMAX® (77 Elektronica, Budapest, Hungary; distributed in Italy by A. Menarini, Florence, Italy), of a new series (sediMAXLite®, sediMAX 2®, and sediMAX conTRUST®) of automated microscopy sediment analyzers was introduced [2]. The sediMAX is a cuvette-based image analyzer with computerized analysis of digital pictures of sediment elements within entire microscopic fields of view similar to those seen by manual microscopy [3] in bright field. Dynamic innovation of this technology has now produced a new and improved instrument, sediMAX conTRUST PRO®, which integrates bright field and phase contrast into one optical system with an HPF-like magnification. It is well known that phase contrast enhances the vision of low-refractive components (hyaline casts, ghost cells) and cellular details. Thus, the combination of the two types of microscopy in a single analyzer allows for the best interpretation of all the urine particles present in each sediment.

These technological innovations sparked our interest, given the routine use of sediMAX for urinalysis testing in our laboratory. We wanted to verify if the addition of automated phase contrast microscopy could indeed provide images by which computerized analysis efficiently identified and classified urine sediment particles. Thus,this study aimed to evaluate the analytical and diagnostic performance of sediMAX conTRUST PRO in relation to urine particle analysis compared to (MM) with phase contrast.

Abbreviations: RBC, red blood cells; WBC, white blood cells; EPI, squamous epithelial cells; NEC, non-epithelial cells; HYA, hyaline casts; PAT, pathological casts; CaOxm, calcium oxalate monohydrate crystals; CaOxd, calcium oxalate dehydrate crystals; TRI, triple phosphate crystals; URI, uric acid crystals; BACc, cocci bacteria; BACr, rod bacteria; YEA, yeast; SPRM, sperm; MUC, mucus

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2. Material and methods

2.1. Study protocol

A total of 504 consecutive anonymous leftover samples from both inpatients and outpatients were collected from February to December 2017 at Desio Hospital, Desio, Italy, for the study. Urines were processed within 2 h after retrieval from the routine laboratory. Urinalysis was performed only using un-centrifuged native urine, first by sediMAX conTRUST PRO and then by MM. Results obtained for each urine sediment by sediMAX conTRUST PRO were compared with those obtained on the same sediment by MM. The particles considered were: red blood cells, white blood cells, squamous epithelial cells, non-epithelial cells, hyaline casts, pathological casts (erythrocyte, leukocyte, granular, etc.), crystals (calcium oxalate dihydrate, calcium oxalate monohydrate, triple phosphate, uric acid), bacteria, yeast, sperm, and mucus.

2.2. SediMAX conTRUST PRO

SediMAX conTrust PRO is a new and improved automated microscopy cuvette-based urine sediment analayzer of the sediMAX series [2]. This particular analyzer combines bright-field and phase-contrast microscopy in one optical system with an HPF-like magnification. It has a new and advanced built-in digital camera which provides both a bright field and a phase contrast microscopic image from the same viewfield. By default 15 high resolution digital gray scale images are taken from different locations on a disposable cuvette bearing urine. These correspond to a total of 2,2 μL of native urine for each sample and the through-put is up to 130 samples/h. In parallel with the analysis of the sample, a special neural based evaluation module of the sediMAX conTRUST PRO controls the process, recognizes, and classifies the urine particles as: red blood cells (RBCs); white blood cells (WBCs); squamous epithelial cells (EPI); non-epithelial cells (NEC); hyaline casts (HYA); pathological casts (PAT); crystals- calcium oxalate monohydrate (CaOxm),calcium oxalate dehydrate (CaOxd), triple phosphate (TRI), uric acid (URI); bacteria- cocci (BACc),rods (BACr); yeast (YEA); sperm (SPRM); and mucus (MUC). The instrument expresses RBC and WBC count quantitatively, and all other particles semi-quantitatively. Counts are given both in p/μL and p/HPF.

2.3. Manual microscopy

MM was carried out using KOVA® Glasstic® slides 10 with grids (KOVA International, Inc., Garden Grove, California, USA)according to ISHL guidelines [4] with resuspension of each sample before transferral to the counting chamber. Manual count was performed in phase contrast by two independent operators, in blind to each other and to sediMAX contTRUST PRO,on different counting chambers. Sediment microscopy was executed in phase contrast at 100× to verify homogeneity and the presence of casts, and at 400× for all other elements. The above mentioned particles were counted and compared to those obtained by sediMAX conTRUST PRO for the same sample.

2.4. LoB, LoD, and LoQ

LoB, LoD, and LoQ were evaluated according to a modified CLSI EP17 [5] protocol where each experiment was performed in one day since there are no reagent lots to evaluate, the only reagent being distilled water.

The experiment for the determination of LoB utilized a particle-free pool created from the surnatant of negative urine samples after centrifugation, and a total of 75 measurements for both RBC and WBC counts were performed.

To estimate RBC LoD we used KOVA® Liqua-Trol with Microscopics (KOVA International, Inc., Garden Grove, California, USA) level 1 (average RBC count 330 p/μL) diluted 1:130 with saline solution in order to obtain an approximate value of LoB ± 2SD. Sixty aliquots of the level 1 solution were measured to obtain the LoD. The LoD for WBCs used KOVA® Liqua-Trol with Microscopics level 2 (average WBC count about 15 p/μL) diluted 1:4 with saline solution and 60 aliquots of this solution were measured.

The LoQ was determined considering a predefined CV goal of 25%; 4 different concentration levels (RBCs at: 5, 10,12 and 14 p/μL; WBCs at: 4, 7, 10, and 13 p/μL) were prepared by diluting KOVA® Liqua-Trol with Microscopics level 1 with saline solution appropriately in order to obtain the above concentrations, and 36 replicates at each concentration were tested.

2.5. Precision

Precision was only determined for those particles (RBCs and WBCs) that are evaluated quantitatively by sediMAX conTRUST PRO, by using KOVA® Liqua-Trol with Microscopics level 1 and 2 according to CLSI EP 15 [6].The low RBC count for within-run precision was obtained by a 1:10 dilution of KOVA® Liqua-Trol with Microscopics level 1 (high count quality control) with saline solution, in order to obtain counts that were different from 0 as found by level 2 (low count quality control). However, RBC low counts could not be assessed for the between-run precision, because the diluted level 1 would have lost stability during the consecutive days necessary for the experiment, and level 2 could not be used because it is negative for RBCs.

2.6. Linearity

Linearity was performed for RBCs and WBCs only, according to CLSI EP 6 [7] using an 11 sample dilution scheme. The high RBC count was obtained by mixing a particle free negative urine pool with 70 μL of whole blood in order to obtain a RBC concentration of around 2000 p/μL, and the high WBC count was obtained by mixing a particle free negative urine pool with the buffy coat of a whole blood sample in order to obtain a final concentration of about 1000 p/μL. The low RBC and WBC counts were obtained from the surnatant of negative urine samples after centrifugation.

2.7. Carry-over

Carry over was evaluated according to Broughton [8] for the three particles which are most frequently present in high concentration: RBC, WBC, and bacteria. Three aliquots of a highly positive concentration for each of the three parameters were firstly measured in sequence, followed by three aliquots of saline solution. This order of measurements was repeated 10 times on sediMax conTRUST PRO.

2.8. Statistical analysis and calculations

Statistical analysis for LoD, LoB, LoQ, precision, and linearity were all determined by Analyse-It computer package (Analyse-It Software, Leeds, UK). Method comparison analysis, using Passing-Bablok regression and McNemar test, was performed by MedCalc statistical software package (MedCalc Software, Osten, Belgium).

3. Results

3.1. LoB, LoD, and LoQ

LoB for RBCs and WBCs resulted to be, respectively, 1.8 and 0.7 p/μL. LoD was 3.9 p/μL for both RBCs and WBCs. The concentration of RBCs and WBCs at which the LoQ satisfied a CV < 25.0%was 12.0 p/μL and 8.0 p/μL, respectively.

Table 1
Within-run and between-run precision for RBC and WBC counts.

Imprecision		RBC			WBC		
		Average Count (p/μL)	SD	CV (%)	Average Count (p/μL)	SD	CV (%)
Within-run	High	349.00	21.64	6.20	225.19	12.61	5.60
	Low	28.92	3.22	11.12	17.10	2.27	13.29
Between-run	High	418.27	17.60	4.21	223.08	20.94	9.39
	Low	/		/	17.38	3.72	21.40

3.2. Precision

Within-run and between-run imprecision for RBCs and WBCs is shown in Table 1. Within-run precision (Table 1) was very good for both the particles at high level counts, and still good at low level counts. A very good precision was maintained at high level counts for RBCs and WBCs during the between-run experiment. Only for WBC low count between-run CV was higher (21.40%).

3.3. Linearity

Linearity was assessed by using Analyse-it software which automatically can apply different fitting models based on the data, and show the percentage of non-linearity for the considered levels. For RBCs, 2 fitting models were applied, linear and 2nd order polynomial, respectively, as shown in Fig. 1. The model that better fits the whole range of p/μL is a 2nd order polynomial. Analyse-it software, in fact, was able to detect a major percentage of non-linearity at 0 and 200 p/μL, respectively. However, linearity was achieved between 3.9 p/μL and 1100 p/μL as also shown in the close-up of Fig. 1. Linearity [Fig. 2] for WBCs was observed ($R^2 = 0.99$) between 3.9 p/μL and 800 p/μL.

3.4. Carry-over

Sample carry-over for RBCs, WBCs, and bacteria resulted to be 0.00%, 0.04%, and 0.00%, respectively. All satisfied the criteria of < 0.05%.

3.5. Method comparison

Method comparison was evaluated by using the Passing-Bablok regression model only for those particles that are assessed quantitatively. Regression results for RBCs and WBCs are shown in Fig. 3 and Fig. 4, respectively. Regression parameters are shown in Table 2.

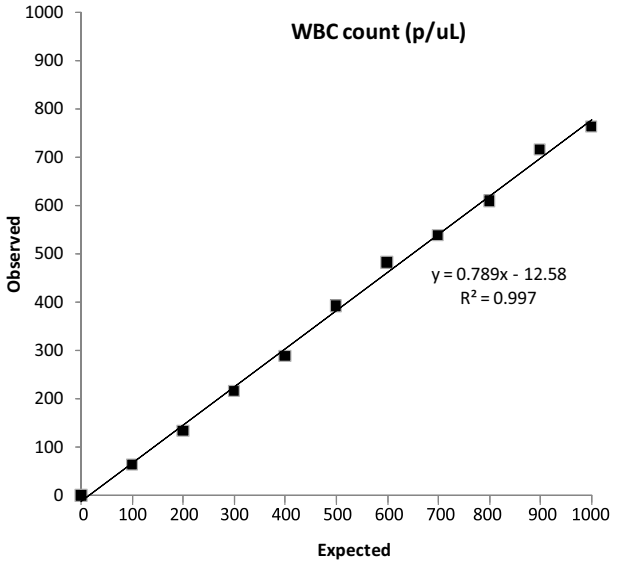

Fig. 2. Oberved vs expected WBC count. Linear range between 0 and 1000 p/μL.

To compare results for all the urine particles considered, cut-offs and grading categories were set as indicated in Tables 3 and 4, and pairwise concordance was determined according to McNemar Test. Results are indicated in Table 5. Positive and negative predictive values were estimated based on the prevalence of urine sediment particles representative of the patient population being served by Desio Central Laboratory [10].

Using the same cut-offs for both MM and sediMAX conTRUST PRO, concordance rate within one grade of agreement was quite high, 97.8% and 98.0% for RBCs and WBCs, respectively. Recognition of "ghost cells" as RBCs improved total RBC count. In the case of EPI, HYA, PAT, and NEC, where proportional cut-offs and grading categories between the two different methods were used, concordance rate within one grade of agreement was above 95.0% for all except NEC where it was 91.5%. Plus and minus one agreement rate for particles graded semi-quantitatively was also above 95% except for BACc and BACr (91.1%

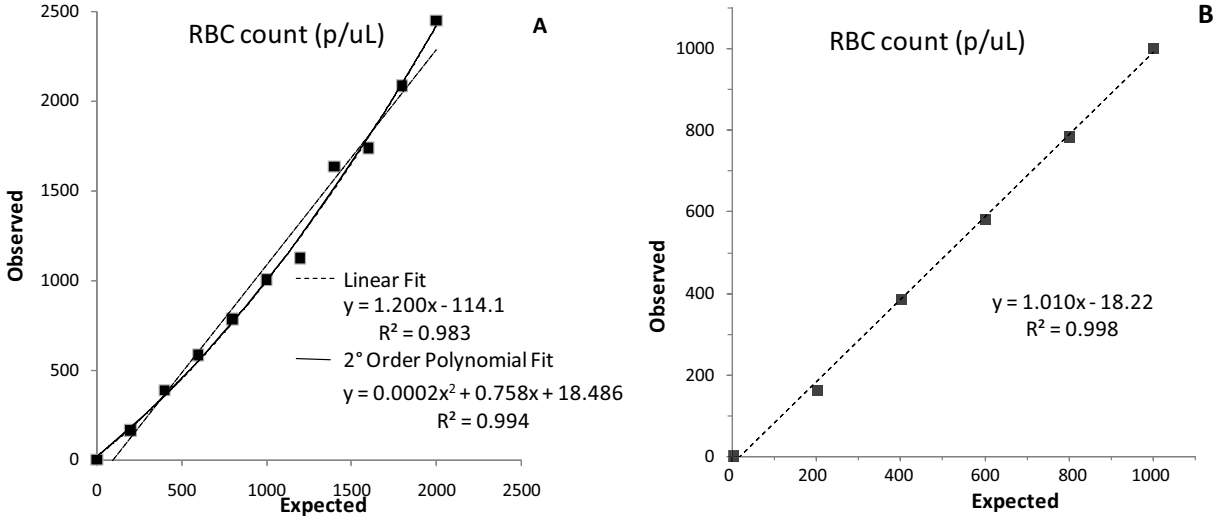

Fig. 1. Observed vs expected RBC count. Panel A shows the linear and polynomial fitting models, respectively, in the 0–2000 p/μL range. Panel B shows the close-up of the linear range between 0 and 1100 p/μL.

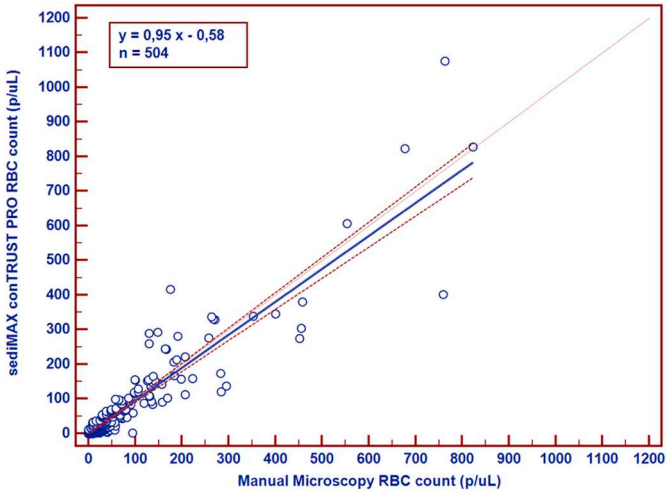

Fig. 3. Comparison between sediMAX conTRUST PRO and Manual Microscopy using the Passing-Bablok regression model for RBC count.

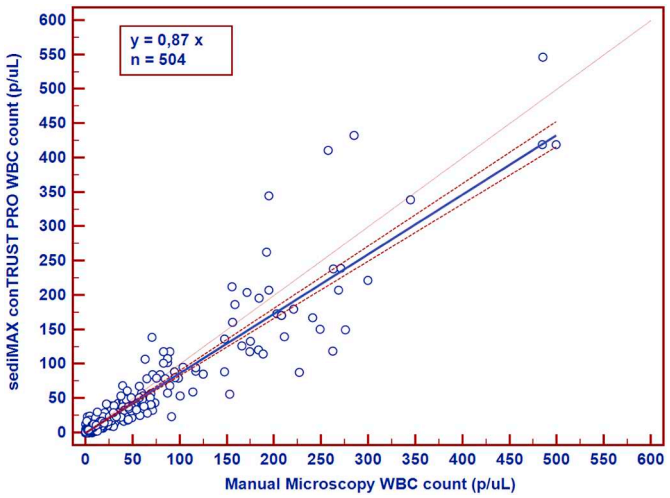

Fig. 4. Comparison between sediMAX conTRUST PRO and Manual Microscopy using the Passing-Bablok regression model for WBC count.

and 93.1%, respectively).

Diagnostic sensitivity and specificity were both > 80.0% for RBC, WBC, EPI, YEA, and BACr. In particular, specificity was above 90.0% for the first four particles, but also for HYA, PAT, and CRY, however, the sensitivities in the latter three cases were below 80.0%. Furthermore, diagnostic performance for NEC in terms of sensitivity was good (84.6%), and of specificity very close to 80.0% (79.9%).

The NPV was higher than 90.0% in almost all of the particles investigated (RBC, WBC, EPI, NEC, HYA, PAT, CRY, YEA, BACc) and very close to 90% for BACr (89.3%). The great fluctuation in the PPVs is due to the different prevalence of each particle type in our patient population.

4. Discussion

The Clinical and Laboratory Standards Institute GP-16 A3 [11] advocates the use of phase optics to enhance the identification of sediment particles. Indeed, phase contrast enhances the vision of low-refractive components (hyaline casts, ghost cells) and cellular details, and many authors confirm its worth in the practice of urinalysis [3,12–16]. Phase contrast optics have been introduced for the first time in an automated urinalysis system, sediMAX conTRUST (commercial name distributed by Menarini Diagnostics; also known as Urised 3 in other countries). With the advent of the sediMAX conTRUST PRO improvements have been made, such as the passage from a LPF-like to HPF-like magnification, thus easing particle identification.

RBC and WBC detection and identification is feasible already at a very low particle concentration as described in results. Within-run precison for both RBCs and WBCs was comparable to that of sediMAX, and sediMAX contrust (Urised 3) (see Table 6). However, between-run

Table 3
Grading systems used for quantitative determination of particles by sediMAX conTRUST PRO (CT) and MM.

Particle	Category				
	A (p/μL)	B (p/μL)	C (p/μL)	D (p/μL)	E (p/μL)
RBC					
MM	0–14	15–29	30–59	60–99	≥100
CT	0–14	15–29	30–59	60–99	≥100
WBC					
MM	0–19	20–39	40–69	70–99	≥100
CT	0–19	20–39	40–69	70–99	≥100
EPI					
MM	0–4	5–14	≥15	/	/
CT	0–2	3–8	≥9	/	/
NEC					
MM	0–4	5–7	8–10	11–13	≥14
CT	0	1–2	3–5	6–8	≥9
HYA casts					
MM	0–2	3–5	6–8	9–11	≥12
CT	0–1	2–3	4–5	6–7	≥8
PAT casts					
MM	0–2	3–4	5–6	≥7	/
CT	0	1–2	3–4	≥5	/

Table 4
Grading systems used for semiquantitative determination of particles by sediMAX conTRUST PRO (CT) and MM.

Particle	Category		
	A	B	C
CRY	Mild	Moderate	Severe
MM	+	+ +	+ + +
CT	+	+ +	+ + +
YEA	Mild	Moderate	Severe
MM	+	+ +	+ + +
CT	+	+ +	+ + +
BACc	Mild	Moderate	Severe
MM	+	+ +	+ + +
CT	+	+ +	+ + +
BACr	Mild	Moderate	Severe
MM	+	+ +	+ + +
CT	+	+ +	+ + +
MUC	Mild	Moderate	Severe
MM	+	+ +	+ + +
CT	+	+ +	+ + +

Table 2
Passing-Bablok parameters for comparison of sediMAX conTRUST PRO with MM.

	Method *y*	Method *x*	Slope (95% CI)	Intercept (counts/μL) (95% CI)	r_s
RBC	MM	sediMAXconTRUST PRO	0.9525 (0.9000–1.0197)	−0.5814 (−1.0133—0.4250)	0.873
WBC	MM	sediMAXconTRUST PRO	0.8667 (0.8333–0.9073)	0.0000 (−0.0815–0.0000)	0.908

Table 5
Diagnostic performance of sediMAX conTRUST PRO compared to MM.

	RBC	WBC	EPI	NEC	HYA	PAT	CRY	YEA	BACc	BACr	MUC
Exact category agreement	82.5	86.1	89.7	75.0	88.3	92.5	89.7	96.6	69.4	83.3	71.4
± 1 category agreement	97.8	98.0	99.8	91.5	96.2	97.0	98.2	99.2	91.1	93.1	98.0
Sensitivity (95% CI)	81.5 (74.9–87.0)	89.5 (83.3–94.0)	86.5 (77.6–92.8)	84.6 (71.9–93.1)	70.6 (52.5–84.9)	61.8 (43.6–77.8)	78.6 (49.2–95.3)	82.4 (56.6–96.2)	95.6 (89.1–98.8)	92.8 (76.5–99.1)	64.0 (55.5–72.0)
Specificity (95% CI)	96.4 (93.8–98.1)	97.0 (94.6–98.5)	94.2 (91.5–96.3)	79.9 (75.9–83.5)	97.0 (95.1–98.4)	97.2 (95.3–98.5)	92.0 (89.3–94.3)	97.9 (96.3–99.0)	71.9 (67.3–76.2)	85.3 (81.8–88.4)	83.6 (79.4–87.2)
Prevalence	11.9	24.0	29.4	3.2	1.2	1.5	12.7	1.0	58.9	58.9	94.2
PPV	75.2 (63.4–84.2)	90.3 (83.8–94.3)	86.2 (80.7–90.3)	12.2 (10.1–14.7)	22.4 (14.1–33.5)	25.4 (15.8–38.2)	59.0 (48.9–68.3)	28.8 (17.4–43.7)	83.0 (80.6–85.1)	90.1 (87.7–92.0)	98.4 (98.0–98.8)
NPV	97.5 (96.6–98.1)	96.7 (94.8–97.9)	94.4 (90.8–96.6)	99.4 (98.8–99.7)	99.6 (99.4–99.8)	99.4 (99.1–99.6)	96.7 (91.5–98.8)	99.8 (99.5–99.9)	92.0 (81.4–96.8)	89.3 (68.7–96.9)	12.5 (10.2–15.2)

Each diagnostic parameter is considered in percentage.

precision for WBCs with sediMAX conTRUST Pro was higher than sediMAX conTRUST and sediMAX, this was probably due to loss of stability of the KOVA® Liqua-Trol with Microscopics level 2.

Regarding the only quantitative particles, RBCs and WBCs, method comparison evaluation by Passing-Bablok regression analysis established a very good correlation, in terms of Spearman's correlation coefficient, between sediMAX conTRUST PRO and MM for RBCs ($r_s = 0.87$), and even better for WBCs ($r_s = 0.91$). These findings were better than those observed with sediMAX [2], the first instrument of the sediMAX series run only in bright field, and similar if not better to those obtained by sediMAX conTRUST [9], the first of the series with phase contrast optics. They were also better than the Cobas 6500 and IQ200 [17]. These improvements with respect to the previous instruments of the sediMAX series are a reflection of the technological innovations made to the sediMAX conTRUST PRO, especially regarding the software and optics, in order to obtain a better identification and classification of particles.

Further analysis of the Passing-Bablok regression showed the presence of a systematic constant error for RBCs and a systematic proportional error for WBCs (Table 2). These results reflect a purely mathematical evaluation of the concordance between the two methods. However, when one considers the clinical significance of the comparison, it is the concordance calculated according to the McNemar test, where classes of particle counts are defined, that has a greater value for diagnostic purposes than the continuous quantitative Passing-Bablok regression. Indeed, based upon the findings with the McNemar test, sediMAX conTRUST PRO RBC and WBC count have excellent within one grade of agreement with MM count, 97.8% and 98.0%, respectively. These results were better than those found by Laiwejpithaya, et al., [9] for the sediMAX conTRUST (Urised 3) and by Sanchez-Mora, et al., [18] for the sediMAX and UX-2000 studied in their global evaluation of 3 different hospital centers, and by Lee, et al., [19] for the UF-1000i. The high grade performance for RBCs by the sediMAX conTRUST PRO is consequent to the enhanced visualization, identification, and enumeration of “ghost cells” as RBCs by the phase contrast opticals. The diagnostic sensitivity and specificity for RBCs and WBCs (see Table 5) at a cut-off of 15 p/μL and 20 p/μL, respectively, was very good and comparable to that found by Previtali et al., [20] with UF-1000i and with the UF 5000 but at lower cut-offs (10 p/μL). In the latter case, one would expect to have fewer false negative results (higher sensitivity than sediMAX conTRUST PRO) and higher false positives (lower specificity than sediMAX conTRUST PRO). On screen review of the images of the samples with false negative results for RBCs and WBCs with sediMAX conTRUST PRO, suggested that about 50% and 85%, respectively, were samples with MM counts just around the cut-off value and the corresponding counts with sediMAX conTRUST PRO were one or two particles less than the cut-off. Especially for the WBC counts, only in about 15% of the cases was there a big difference between the sediMAX conTRUST PRO and MM, and this was due to cell clumping.

The McNemar test for the remaining particles also substantiates an excellent within one grade of agreement for all (above 95.0%) except for NEC, BACc and BACr. The concordance for the latter particles was, however, still good (91.5%, 91.1%, and 93.1%, respectively) as shown in Table 5. Furthermore, performance for this group of particles in terms of diagnostic sensitivity was overall very good. In the case of hyaline (sensitivity 70.6%) and pathological casts (sensitivity 61.8%) performance seemed inferior, but when compared to other automated systems such as UX 2000, and Cobas 6500 [21] it was greater. Additionally, the improved visualization of particles with a low-refractive index, such as hyaline casts, determined by the new phase contrast opticals has induced an upgrade in the sediMAX conTRUST PRO's performance for these elements respect to the previous instruments of the sediMAX series: Urised (distributed as sediMAX by Menarini Diagnostics) (hyaline cast sensitivity 52%) [22], Urised 3 (hyaline cast sensitivity 66.7%) [9]. Phase contrast also intensifies the vision of bacteria in the urine sediment. This is supported by the very good

Table 6
Within-run and between-run precision expressed as CV%.

		Within-run precision				Between-run precision			
		Low		High		Low		High	
Analyzer	Parameter (p/μL)	Mean	CV%	Mean	CV%	Mean	CV%	Mean	CV%
SediMAX ConTRUST PRO	RBCs	28.92	11.12	349.00	6.20	/	/	418.27	4.21
	WBCs	17.10	13.29	225.19	5.60	17.38	21.40	223.08	9.39
SediMAX ConTRUST (Urised 3)	RBCs	18.14	16.40	101.87	12.60	20.90	15.60	127.35	9.10
	WBCs	11.04	16.20	43.11	11.20	12.28	16.10	49.91	8.50
SediMAX	RBCs	7.00	17.80	447.00	6.70	30.00	14.70	283.00	7.20
	WBCs	4.00	16.60	258.00	4.40	25.00	5.40	166.00	3.00

sensitivity observed for bacteria in this study (BACc = 95.6%; BACr = 92.8%). Nevertheless, specificity for BACc is 71.9%, and this may be due to the difficulty both by MM and by sediMAX conTRUST PRO in distinguishing cocci from small debris, small lipid droplets, or amorphous material.

Finally, with the exception of mucus which was not taken into consideration in this study, a high NPV was found for all the particles evaluated by the sediMAX conTRUST Pro, indicating the exclusion of disease when the urine sediment being evaluated was negative.

5. Conclusions

The modifications made towards the development of the sediMAX conTRUST PRO did not alter in any way the practicality offered by the preceding analyzers of its line. Reagent handling is easy, the only reagent being deionized water. Liquid waste is managed by collection in a plastic bottle and no particular precautions must be taken for elimination. The cuvettes necessary for urine sediment testing can be loaded without difficulty and easily disposed after use. For new utilizers of contrast phase optics, the skills needed for learning, understanding, and interpreting this type of microscopy can be acquired by the concurrent vision in bright field of the same viewfield. Finally, the on screen revision of a particular urine sediment contemporaneously by both types of microscopy permit to obtain all the advantages given by each in terms of qualities, detail, and definition of the urine particles.

In conclusion, the most recent automated urine sediment analyzer, sediMAX conTRUST PRO, has undergone innovations which have improved its performance with respect to its predecessors while maintaining practicality. The integrated optical system (bright field and phase contrast) has further refined the identification, classification, and enumeration of all particles. The special neural based evaluation module integrates the information contained in the same viewfield observed both in bright field and phase contrast allowing to capture the details provided by both types of microscopy thus ameliorating the performance for each particle that may be present within the urine sediment.

Conflict of interest

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] J. Delanghe, New screening diagnostic techniques in urinalysis, Acta Clin. Belg. 62 (2007) 155–161.
[2] Z. Zaman, G.B. Fogazzi, G. Garigali, M.D. Croci, G. Bayer, T. Kranicz, Urine sediment analysis: analytical and diagnostic performance of sediMAX® - Anew automated microscopy image-based urine sediment analyser, Clin. Chim. Acta 411 (2010) 147–154.
[3] G.J. Becker, G. Garigali, G.B. Fogazzi, Advances in urine microscopy, Am. J. Kidney Dis. 67 (2016) 954–964.
[4] T. Kouri, A. Gyory, R.M. Rowan, ISHL recommended reference procedure for the enumeration of particles in urine, Lab. Hematol. 9 (2003) 58–63.
[5] CLSI, Evaluation of detection capability for clinical laboratory measurement procedures, CLSI Document EP17-A2, Second Edition, Clinical and Laboratory Standards Institute, Wayne PA, 2012.
[6] CLSI, User verification of precision and estimation of bias; approved guideline, CLSI Document EP15-A3, Third Edition, Clinical and Laboratory Standards Institute, Wayne PA, 2014.
[7] CLSI, Evaluation of the linearity of quantitative measurement procedures: a statistical approach; approved guideline, CLSI Document EP06-A, Clinical and Laboratory Standards Institute, Wayne PA, 2003.
[8] P.M.G. Broughton, A.H. Gowenlock, J.J. McCormack, D.W. Neil, A revised scheme for evaluation of automatic instruments for use in clinical chemistry, Ann. Clin. Biochem. 11 (1974) 207–218.
[9] S. Laiwejpithaya, P. Wongkrajang, K. Reesukumal, C. Bucha, S. Meepanya, C. Pattanvin, V. Khejonnit, A. Chuntarut, Urised 3 and UX-2000 automated urine sediment analyzers vs manual microscopic method: a comparative performance anlysis, J. Clin. Lab. Anal. 32 (2018) 1–10.
[10] R. Palmieri, R. Falbo, F. Cappellini, C. Soldi, G. Limonta, P. Brambilla, The development of autoverification rules applied to urinalysis performed on the AutionMAX-sediMAX platform, Clin. Chim. Acta 485 (2018) 275–281.
[11] CLSI, Urinalysis; approved guideline, CLSI Document GP16-A3, Third Edition, Clinical and Laboratory Standards Institute, Wayne PA, 2009.
[12] K.F. Fairley, D.F. Birch, Hematuria: a simple method for identifying glomerular bleeding, Kidney Int. 21 (1982) 105–108.
[13] H. Kohler, E. Wandel, B. Brunck, Acanthocyturia- a characteristic marker for glomerular bleeding, Kidney Int. 40 (1991) 115–120.
[14] K.S. Mohammad, A.S. Bdesha, M.E. Snell, R.O.N. Witherow, D.V. Coleman, Phase contrast microscopic examination of urinary erythrocytes to localise source of bleeding: an overlooked technique? J. Clin. Pathol. 46 (1993) 642–645.
[15] J.A.T. Poloni, I.B. Bosan, G. Garigali, G.B. Fogazzi, Urinary red blood cells: not only glomerular or nonglomerular, Nephron. Clin. Pract. 120 (2012) c36–c41.
[16] G.B. Fogazzi, J. Delanghe, Microscopic examination of urine sediment: phase contrast versus bright field, Clin. Chim. Acta 487 (2018) 168–173.
[17] E. Bakan, N. Ozturk, N.K. Baygutalp, E. Polat, K. Akpinar, E. Dorman, H. Polat, N. Bakan, Comparison of Cobas 6500 and Iris IQ200 fully-automated analyzers to manual urine microscopy, Biochem. Med. 26 (2016) 635–675.
[18] C. Sanchez-Mora, D. Acevedo, M.A. Porres, A.M. Chaques, J. Zapardiel, A. Gallego-Cabrera, J.M. Lopez, J.M. Maesa, Comparison of automated devices UX-2000 and sediMAX/AutionMAX for urine samples screening: a multicenter Spanish study, Clin. Biochem. 50 (2017) 714–718.
[19] W. Lee, J.S. Ha, N.H. Ryoo, Comparison of the automated cobas u 701 microscopy and UF-1000i flow cytometry systems and manual microscopy in the examination of urine sediments, J. Clin. Lab. Anal. 30 (2016) 663–671.
[20] G. Previtali, R. Ravasio, M. Seghezzi, S. Buoro, M.G. Alessio, Performance evaluation of the new fully automated urine particle analyser UF-5000 compared to the reference method of the Fuchs-Rosenthal chamber, Clin. Chim. Acta 472 (2017) 123–130.
[21] B. Wesarachkitti, V. Khejonnit, B. Pratumvinit, K. Reesekumal, S. Meepanya, C. Pattanavin, P. Wongkrajang, Perormance evaluation and comparison of the fully automated urinalysis UX-2000 and Cobas 6500, Lab. Med. 47 (2016) 124–133.
[22] P. Bottini, M.H.M. Martinez, C. Garlipp, Urinalysis: Comparison between microscopic analysis and a new automated microscopy image-based urine sediment instrument, Clin. Lab. 60 (2014) 693–697.