

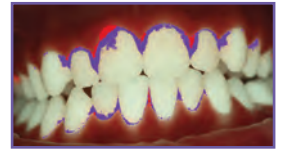
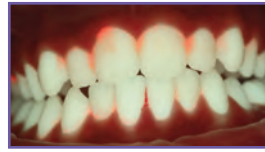
# WHITE PAPER ON QLF



First photo: white light image



Second photo: fluorescence image



Analysis

# **Application of QLF™ for Diagnosis and Quality Assessment in Clinical Practice**

Version : 11, 2012-06-18  
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## ***Summary***

Diagnosis and quality assessment of dental treatment in a general dental practice is firmly based on tactile and visual assessment, either directly or indirectly through (digital) imaging using white light photography or X-rays[1]  
Considerable effort has been made to objectify this basically subjective procedure into well-defined scoring systems (e.g. ICDAS, DETI, DPSI) [2, 3, 4]  
Nevertheless there remains a need for an objective, reproducible, exchangeable, easy-to-use and cost-effective method to document, diagnose, monitor, demonstrate, evaluate and share a significant part of the daily activity in a dental practice: patient intake, oral hygiene issues and treatment, early caries detection and prevention, minimal invasive treatment, excavation (simple as well as root-canal) assessment, assessment of existing sealants and restorations and ‘hidden’ (sub-surface and approximal) caries.

This paper proposes and demonstrates the use of QLF™ (Quantitative Light-induced Fluorescence) to fill this need. It explains the workings of QLF™, the equipment needed to implement its use and then demonstrates how QLF™ can be and is used to fulfill all of the tasks mentioned above in a Dutch clinical setting.

In the discussion, an effort is made to describe how the use of QLF™ could be integrated profitably for all parties concerned into the experimental reform of oral care remuneration (Experiment Vrije Prijzen Mondzorg) in the Netherlands, started in 2012 as the basis for a new, quantitative and reproducible indicator for the quality of dental treatment.

## ***Introduction***

QLF™ (see below for an explanation of the technology) has been around since 1994 and has become the de-facto standard of in vivo measurement of de- and remineralization[5, 6, 7, 8].

In the literature the possibility and advantages of its use in the general dental practice is often mentioned[9, 10]. However, many reasons inhibited the acceptance by clinicians: unfamiliarity, too complex, too time consuming, too expensive and having no remuneration code being the most pertinent ones.

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With the introduction of a new QLF™ system, the QLF-D Biluminator™ 2, acceptance by dental professionals has become a reality. This paper summarizes the current state of the clinical application of QLF™, its potential for clinical practice and suggests directions for further studies.

## **Methods and means**

QLF™, which stands for Quantitative Light-induced Fluorescence [9, 11], raises the visual contrast between sound and pathogenic tissue in the oral cavity. It is based on the fact that various (organic) substances in the mouth absorb light of a certain wavelength (color) and then re-emit the absorbed energy at a different wavelength. By filtering away the illuminating light the *fluorescence-* or *QLF™-image* is obtained.

In these images de-mineralized areas (e.g. white spots) show up as dark-spots, where loss of fluorescence correlates with mineral loss [12].

Areas where porphyrins, generated by (anaerobic) bacterial activity have accumulated show up brightly red/orange (Red Fluorescence or RF areas) [13, 14, 15].

These effects can be observed visually, documented digitally and quantified. Table 1 lists the various parameters that can be obtained using QLF™.

For an extensive description of QLF™ see the following references [9, 10].

The Simple Plaque Score™ and the Two-Tone Plaque Score™ are new additions to the analytical abilities of QLF™ and were introduced at the end of 2011.

The proposals are based on our experience with QLF™ over the last 20 years and the work of Monique van der Veen et al. (IUPUI, Indianapolis, USA and ACTA, Amsterdam, NL), the group of Prof. Susan Higham (University of Liverpool, UK) and many others.

The most important source on the clinical application of QLF™ originates from the work of Karen van Daelen et al. (Samenwerkende Tandartsen Tilburg-Noord (SWT-TN), Tilburg, NL) where QLF™ has been used in a purely clinical setting since 2005.

## **Equipment**

The equipment used consists of the Inspektor™ Pro, the QLF-D Biluminator™ 2 and the QLF™ On-Line tower, all developed and sold by Inspektor Research Systems bv and depicted in Figure 1.

The Inspektor™ Pro was introduced in 2004. It is an intra-oral camera for making QLF-images™ of individual element surfaces. See Figure 1. The Inspektor™ Pro software is used to analyze the images. The analysis procedure consisted of manually selecting the area of interest and defining a reference area. The Inspektor™ Pro is predominantly used for research (with the exception of SWT-TN) and has laid the foundation for the validation of the technology, particularly for the in vivo measurement of de- and remineralization.



**Figure 1.** The equipment used. On the left the Inspektor™ Pro. In the middle the QLF-D Biluminator™ 2 and on the right the QLF™ On-Line tower.

The QLF-D Biluminator™ 2 consists of a Biluminator™ mounted on a Single Lens Reflex (SLR) camera fitted with a 60mm macro lens. The Biluminator™ provides the light sources and filters for making white-light and QLF™-images and a connection to a computer that runs the necessary software for archiving and analysis.

Initiated either by hand or under computer control, the system takes two successive pictures: one standard white light image and one QLF™-image (Figure 2). The average duration of this procedure is less than 5 seconds.



**Figure 2.** Example of the images taken semi-simultaneously with the QLF-D Biluminator™ 2. To the left the 'normal' white light image. In the middle the corresponding QLF™-image. Note the absence of reflections and the red fluorescence in the QLF™-image. Also note the correspondence of the areas with RF and plaque seen on the white light image.

All standard views of dental SLR photography are supported: Frontal, Frontal extended, Lateral, Lingual, Occlusal as well as facial (white light) photography. Disposable cheek retractors and mirrors were used as in normal dental SLR procedures.

The images are stored and analyzed (semi-)automatically for demineralization and red fluorescence or for Two-Tone Plaque Score if applicable. Analysis for de- and remineralization and RF is based on the same algorithms as used in the Inspektor™ Pro system and the correlation of the results is very good (See *Validation* below).

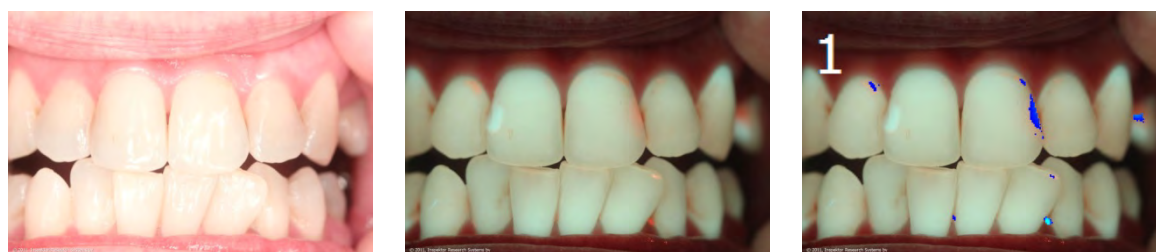
In the case of the dental practice in Tilburg, the images were integrated in the office administration software (Exquise® and VisiQuick). This provides documentation and monitoring over time and supports information exchange.

The QLF™ On-Line tower is an interactive stand-alone system. The tower includes a QLF-D Biluminator™ 2 a computer and a touch screen. The system is fitted with QLF™ On-Line software that guides the user through the process of filling out a questionnaire and the making of a frontal QLF-D image set. The resulting set and the automatically calculated Simple Plaque Score™ are then shown on screen together with a pre-configured advice. These data are also sent to the persons e-mail address, if specified. An example is shown in Figure 3.

The system is very well suited for demonstrations and exhibitions as well as demographic or marketing research. Versions of the tower were used in the exhibition ‘Say Cheese’ in the Boerhaave Science Museum and in the manifestation ‘Show Your Teeth For Serious Request’, both in Leiden, Netherlands, 2011.

During the Boerhaave exhibition more than 16.000 images were made in the 6-month period that the exhibition showed.

During the 6 days of the 3FM Serious Request event almost 1200 people were photographed. Their score and the simple questionnaire they filled in has provided the first validation data for the SPS™.



**Figure 3.** Example of the results produced by the QLF™ On-Line software. **a.** White light image. **b.** QLF™ image **c.** Analysis result for Simple Plaque Score™ superimposed on QLF™ image. The white number represents the value of the Simple Plaque Score™, the blue areas indicate where the software found pixels with significantly raised amounts of RF. (Pictures made with the QLF™ On-Line tower in the TNO-bus during the manifestation 3FM Serious Request, Leiden, NL, December 2011)

Most of the pictures and analyses shown in this paper were made with the QLF-D Biluminator™ 2 system. They originate from the ‘Say Cheese’ exhibition in the Boerhaave Science Museum in Leiden, NL, 2011, the manifestation ‘Show your teeth for Serious Request’, Leiden, NL, 2011, SWT-TN in Tilburg, ACTA in Amsterdam all in the Netherlands.

The pictures of an excavation were made by P. Sas, dentist in Amsterdam, Netherlands with the Inspektor™ Pro.

## Analysis and quantification

Table 1 lists the various parameters that can be obtained using QLF™.

Table 1. Quantitative parameters obtained with QLF

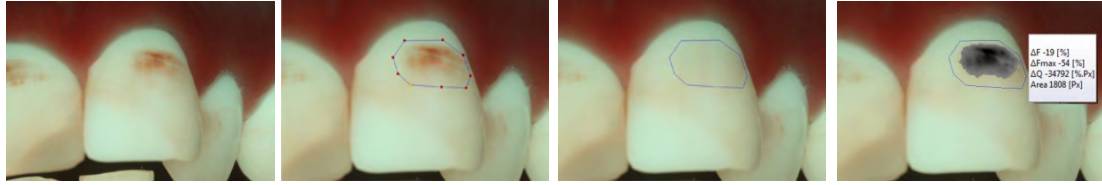
Name	Symbol	Unit	Description
Delta F	$\Delta F$	%	Percentage fluorescence loss with respect to the fluorescence of sound tooth tissue. Related to lesion depth.
Delta Q	$\Delta Q$	%px <sup>2</sup>	Percentage fluorescence loss with respect to the fluorescence of sound tissue times the area. Related to lesion volume.
Lesion Area	$A_{\Delta F}$	px <sup>2</sup>	Area with $\Delta F$ equal or smaller than a specific threshold value of $\Delta F$ (default -5%).
Delta R	$\Delta R$	%	Percentage of increase of the ratio of the red and the green component with respect to that ratio of sound tissue. Related to the presence of porphyrins and indirectly related to bacterial activity.
RF Area	$A_{\Delta R}$	px <sup>2</sup>	Area with $\Delta R$ equal or higher than a specific threshold value of $\Delta R$ .
Simple Plaque Score™	SPS™	-	A value from 0 (no mature plaque) to 5 (high amount of mature plaque).
Two-Tone Plaque Score™	TTPS™	%	Percentages of tooth area covered by mature (dark-blue) and immature plaque (pink-blue).

All these parameters are computed by selecting, either automatically or manually, the area of interest in an image. Within this area a reference is automatically generated or manually selected. Next a value is computed for each pixel in the area of interest. These pixel values are then compared to the average value of all pixels in the reference area. This permits the calculation of area size and average value over the area as a function of a threshold value.

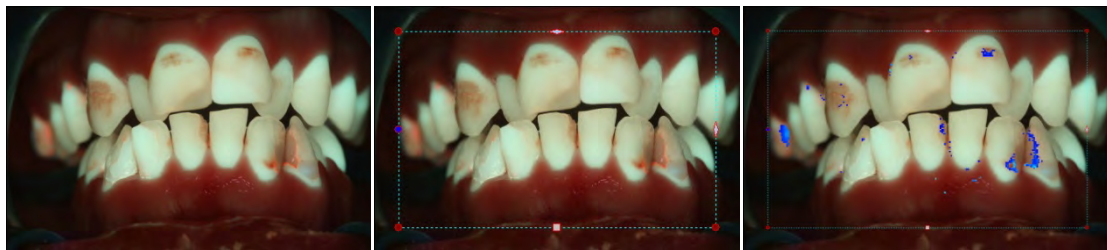
The area is generally expressed in pixels<sup>2</sup> (px<sup>2</sup>). Through calibration this value can be converted into mm<sup>2</sup>.

From these basic results the parameters in Table 1 are derived.

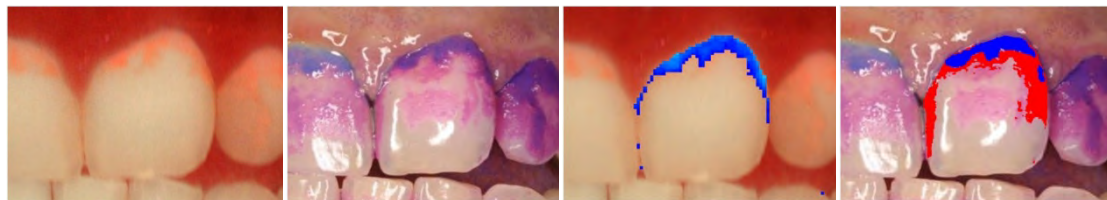
Examples of the analysis procedure are shown below.



**Figure 4.** Example of white spot analysis. **a.** Detail of original QLF™-image. **b.** Manual selection of the area of interest. The contour of the area should lie as much as possible on sound enamel. **c.** Automatically generated reference image which is a virtual reconstruction of the original sound surface. **d.** Visual indication on the original image of the fluorescence loss in each pixel in the selected area. Only pixels with a fluorescence loss below a certain threshold value are shown (*images courtesy Inspektor Research Systems bv*).



**Figure 5.** Example of red fluorescence (RF) analysis. **a.** Original QLF™- image. **b.** Automatically generated contour for the area of interest. **c.** Visual indication on the original image of all pixels that contributed to the resulting Simple Plaque Score™ shown in the upper left corner. Other obtainable results are the area and average increase in RF as a function of a threshold value (*image made by Karen van Daelen, SWT-TN, analysis by Inspektor Research Systems bv*).



**Figure 6.** Example of Two-Tone Plaque Score. Unlike the other two examples, this analysis is done on the white light image. **a.** QLF™-image showing red fluorescence. **b.** Corresponding white light image of teeth after colouring with Two-Tone Plaque disclosing solution. **c.** Visual indication of all pixels that show significant RF. **d.** Two-Tone Plaque analysis showing the areas with mature plaque (coloured blue) and immature plaque (coloured red). Note the good visual agreement between the area of mature plaque detected in the Two-Tone image and the area detected in the QLF™ image. (*images courtesy of Monique van der Veen, ACTA, analysis by Elbert de Josselin de Jong, Inspektor Research Systems bv*)

## Validation

The use of QLF™ for measuring de- and remineralization in vivo and in vitro has been studied and used extensively [12, 8, 11, 16, 5, 6, 17, 18]. All of these studies have been done with the Inspektor™ Pro. The algorithms used in the Inspektor™ Pro software for the computation of  $\Delta F$  and  $\Delta Q$  are basically identical to those used for the QLF-D Biluminator™ 2 [19].

Validation of the interpretation of values generated by the RF analysis is less well supported.



Clinical experience suggests that RF correlates with the presence of mature plaque and calculus. It also suggests that RF detected in a demineralized area or a fissure or a clean, sound surface signifies an active lesion. These suggestions are by no means proven but recent results seem to support them.

The production of RF by porphyrins is rather well documented [20, 21]. Some success has been reached in isolating bacteria that generate RF, most of them being associated with gingivitis or periodontal disease [22].

Initial attempts to link  $\Delta R$  and  $A_{\Delta R}$  values to plaque as disclosed by means of a plaque- disclosing solution have been inconclusive [23, 24, 15, 25].

Recently, new results are emerging that are more successful.

In Liverpool, at the 2011 International Conference on QLF (ICQ 2011), the first study relating ranges of values of  $\Delta F$  and  $\Delta R$  to ICDAS and histology scores by Manal Allammari *et al.* was presented. Table 2 lists the value ranges found by that study. They form a very workable framework for further validation.

Table 2. ICQ 2011 in vivo Index Manal Allammari et al. 2010

QLF SCORE	ICDAS SCORE	DESCRIPTION	$\Delta F$	$\Delta R$
0	0	Sound tooth surface	-0,5 .. -12	0 .. 20
1	1	First visual change in enamel	-12,5 .. -18	21 .. 35
2	2	Distinct visual change in enamel	-18,5 .. -26	36 .. 60
3	3	Localized enamel breakdown because of caries with no visible dentin or underlying shadow	-26,5 .. -32	61 .. 88
	4	Underlying dark shadow from dentin with or without localized enamel breakdown	-32,5.. -38	89 .. 95
4	5	Distinct cavity with visible dentin	-38,5 .. -48	96 .. 110
	6	Extensive distinct cavity with visible dentin	> 48,5	> 110

Table 3. ICQ 2011  $\Delta F$  (%) Average comparison to histology.

QLF INDEX	HISTOLOGY SCORE	DESCRIPTION	$\Delta F$ (%) Average
0	0	Sound tooth surface	-0,5 .. -10
1	1	First visual change in enamel	-10,5 .. -15
2	2	Distinct visual change in enamel	-15,5 .. -25
3	3	Localized enamel breakdown because of caries	-25,5 .. -35
4	4	Distinct/extensive cavity with visible dentin	-35,5 .. -45



An explorative study using two-tone plaque-disclosing solution has shown a remarkable agreement between the areas of mature plaque shown by the plaque-disclosing solution and the areas showing RF [26].

The results of the 3FM Serious Request events were used to link the Simple Plaque Score™ to differences in Gender, Age, Social Economic Status and oral hygiene procedures (brushing frequency).

SPS™ showed significant differences over these parameters and these differences are comparable to those shown by traditional methods such as DMFS[27, 28, 29].

This suggests that SPS™ is a cheap, fast and reliable assessment tool for epidemiological studies with the added benefit of collecting much more detailed information about the state of oral health of the participants.

Many publications report on the positive motivational effect of sharing QLF™ images to patients [9, 30, 31, 32] but to date no specific effort has been made to study and quantify this effect. This year, a study is planned that will compare the effects on oral hygiene of patients when instructed with and without the use of QLF™ images.

Pure clinical validation is scarce. At the moment a study is underway that retrospectively compares diagnosis of tooth surfaces with a low ICDAS score with and without the use of QLF™ with the longer term outcome.

Preliminary data show a much higher sensitivity and specificity for diagnosis with QLF™ but these results have yet to be published and confirmed.

The single practice to date that has integrated QLF™ in their daily routine report a successful use for the intake and monitoring of orthodontic treatments, time savings, enhanced patient compliance and a steady increase in their confidence in the results of the method in the diagnosis of incipient caries [see Appendix 1].

In conclusion it can be said that validation for in vivo measurement of de- and remineralization is good and the prospects of using QLF™ for measuring plaque, assessment of oral health, assessment of caries risk and early caries diagnosis are very promising.

## ***Clinical application of QLF™***

### **Patient intake**

The patient intake sets the baseline for the relation between dental professional and patient. Normally this consists of a tactile and visual inspection, the results of which are documented manually in the patient status and communicated (if at all) to the patient verbally. Sometimes one or more X-rays are made on the basis of the results of this inspection.

The use of QLF™ changes this procedure somewhat radically. In Figure 7 the standard set of images that can be made with QLF-D Biluminator™ 2 are shown. The total time needed to make these pictures averages around 5 minutes. The images will be stored for later reference as part of the patient status and can be shared with the patient (digitally or in hard-copy).



Figure 7. Example of the imaging possible with the QLF-D Biluminator showing the various views that can be taken. To the left the 'normal' white light images, On the right the corresponding QLF™-images. Note the absence of reflections and the distinctive RF in the QLF™ image, especially around the lingual wire and on the tongue. (*images courtesy of Monique van der Veen, ACTA*)

After the images are made they are shown at the chair (on a specially mounted screen or tablet PC) and discussed with the patient.

Experience indicates this procedure significantly improves interaction, understanding and compliance of the patient[32].

Experience also indicates that this use of QLF™ saves time.

Practitioners reported time savings in the order of 50% and a significant improvement in the assessment of the state of the patients oral health [personal communication with J. Van Loock<sup>4</sup>].

The set of images taken during intake form a much more detailed and reliable reference of the state of the oral health of the patient than the standard paper version. Detailed analysis can be performed prospectively as well as retrospectively. Thereby these images can be used to justify and evaluate treatment decisions objectively.

An example of an extensive protocol for the use of the QLF-D Biluminator™ was published in the Quality Practice magazine for hygienists last March (Year 3, Issue 3, March 2011).

<sup>4</sup> Dentist and Chef de Clinique at SWT-TN.

## Oral hygiene diagnosis and treatment evaluation

QLF™ enhances the contrast between areas where porphyrins have accumulated (e.g. mature dental plaque and calculus) and areas where they have not.

The porphyrins show up orange/red and can be detected easily, even by the untrained eye.

This makes the images very useful for the dental professional as well as for the patient to become aware of and to agree on the issues at hand.

According to clinical professionals, using these images to explain oral hygiene issues to the patient is more effective and saves time compared to just verbal communication [see Appendix 1].

Patients on the whole seem to prefer this approach to looking at their own teeth through a mirror and they definitely prefer it to using plaque disclosure agents.

Because QLF™-images can be made quickly and easily, ‘before and after’ images of treatments can be made to check and demonstrate that the treatment was successful and complete. An example is given in the pictures of Figure 8 that shows the same set of teeth before and after a professional cleaning.

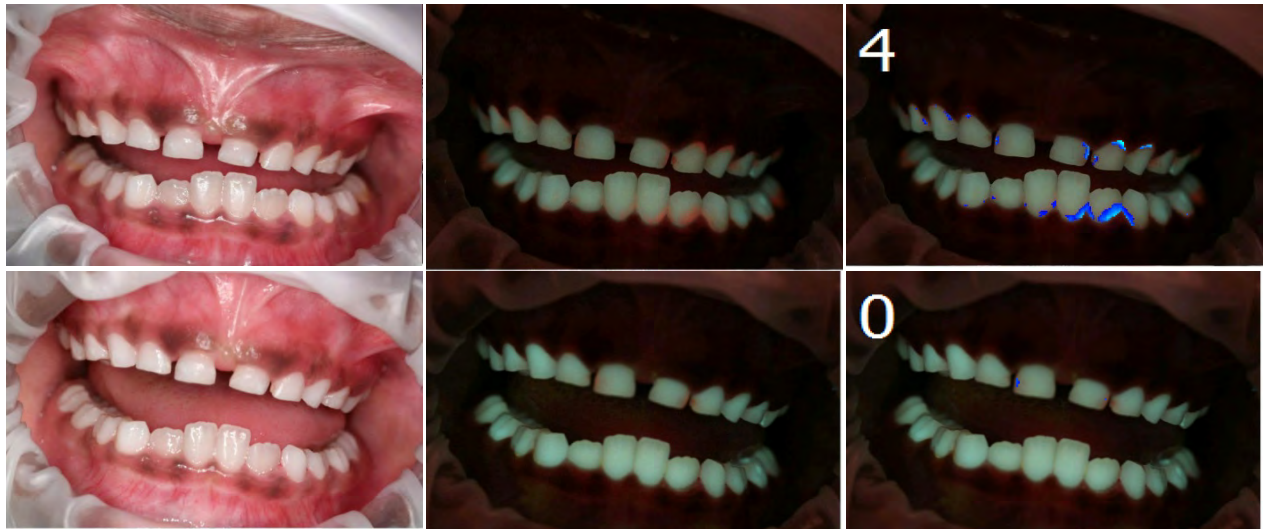


Figure 8. The top row shows images taken before a professional cleaning. The bottom row shows the same teeth after the cleaning has been performed. Note the remaining RF between the upper incisors. Together with signs of demineralization they are strong indicators for active early caries lesions (*images courtesy of Karen van Daelen, SWT-TN*).

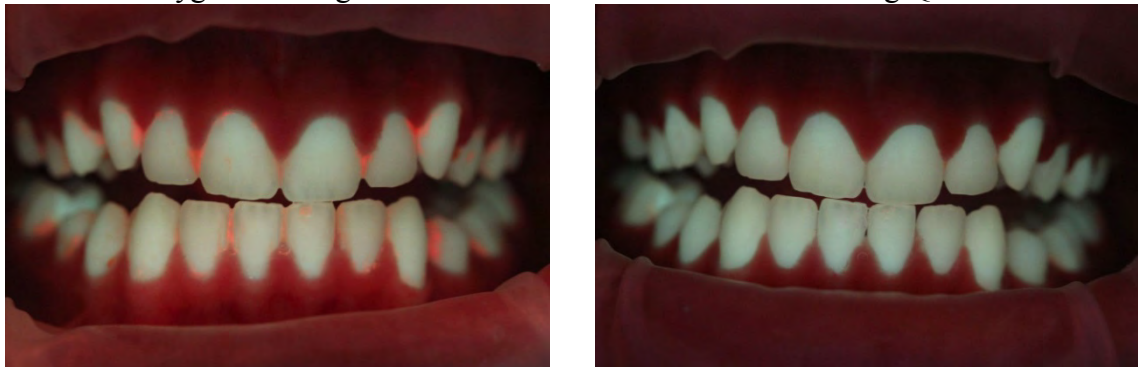
It will be clear from these images that both patient and professional can get a good and objective measure for the effectiveness of the applied treatment.

## Orthodontic treatment

Many studies have shown that orthodontic treatment provides serious health risks if not combined with good oral hygiene at the start, and a vigorous oral hygiene regimen during the orthodontic treatment [33, 34].

QLF™ can help by providing an objective assessment of the state of the oral hygiene before starting the treatment, monitoring and thereby helping to maintain oral hygiene during treatment, and documenting the state of oral hygiene and tooth-elements after the treatment [30, 35, 9].

In Tilburg, QLF™ images are now made routinely of **all** patients starting orthodontic treatment. Images are taken before the orthodontic treatment is started and they determine the decision whether or not to start the treatment. Patients that seem to fail in their oral hygiene during orthodontic treatment are monitored using QLF™.



**Figure 9.** Example of the assessment of oral hygiene before the start of the orthodontic treatment. This patient had a Simple Plaque Score of 5 (image on the left). The patient was shown these images and told orthodontic treatment would not start unless the oral hygiene improved. The patient received oral hygiene instructions and was sent home. After three weeks the patient returned and a new QLF™-image was made (image on the right) now showing an SPS of 0. Orthodontic treatment was then started (*images courtesy of Karen van Daelen, Samenwerkende Tandartsen Tilburg Noord*).

This has made an end to discussions about whether or not treatment can be started and is expected to seriously mitigate any adverse effects of the treatment.



**Figure 10.** Example of deficient oral hygiene during orthodontic treatment (*images courtesy of Karen van Daelen, SWT-TN*).

Furthermore the images provide an objective proof of the existence or absence of these adverse effects after the treatment.





**Figure 11.** Example of severe effects of orthodontic treatment taken after de-bracketing. Note that, although in this case most lesions show up as white spots they are more easily detected in the QLF™-image. Also, the RF information provides a clear and strong indication about the activity in each of these lesions (*images courtesy of Karen van Daelen, SWT-TN*).



**Figure 12.** example of assessment of the effects of orthodontic treatment. Treatment was stopped. The appliance was removed and diagnosis with QLF™ confirmed with X-ray (*images courtesy of Karen van Daelen, SWT-TN*).

### Early caries diagnosis and treatment evaluation

Good early caries diagnosis is believed to be essential for any serious preventive treatment[36].

With current methods it is often difficult to assess the threat posed by areas that show early caries signs (such as white spots or discolored fissures).

QLF™ images not only make it easier to detect these areas, they also improve and objectify the assessment of these areas based on the measured values of  $\Delta F$  and  $\Delta R$  for these areas (see images in Figure 13).



**Figure 13.** Early lesions as seen by white-light (on the left) and QLF™ (on the right). Note combination of demineralization (darker area) and RF (*images courtesy of Karen van Daelen, SWT-TN*).

Additionally they allow monitoring in time to objectively assess progression, stability or even regression of the caries process in these areas, thus providing objective support for (changes in) treatment decisions.

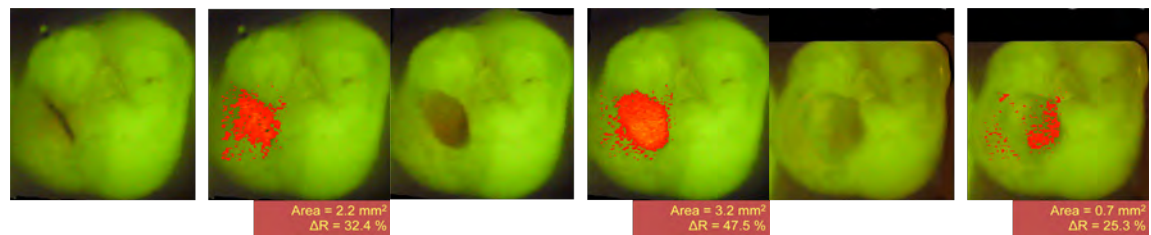
In Tilburg, over a period of 6 years, about 300 patients with areas that showed early signs of caries activity have been assessed separately and independently by standard visual inspection and with the use of QLF™. These assessments and the treatment decision were documented and the areas were then followed over time.

Preliminary results strongly indicate that assessment with QLF™ can predict the outcome for these areas better than the standard procedure and that it can be used to decide between ‘no treatment’, preventive measures (fluoride application, sealant) and restorative action (minimal invasive action or restoration).

### Excavation assessment

Just as QLF™ discloses de-mineralization and accumulation of porphyrins on tooth surfaces, QLF™ can disclose these phenomena during excavation.

It is then used to support decisions about the extent of the excavation [37, 38] and can be used as documentation to the state of the element prior to filling.



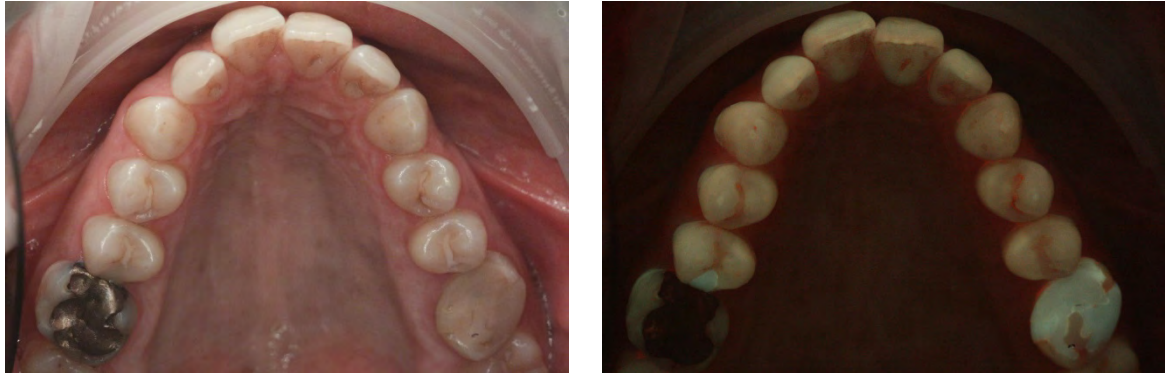
**Figure 14.** Use of QLF™ during excavation (images made with the Inspektor™ Pro). From left to right: Discolored fissure that shows RF; After opening the fissure a dentine lesion is exposed with corresponding increase in RF. The excavation prior to preparation. Some RF is still present (*Images made by P.Sas, Amsterdam, Netherlands*).

Efforts have been done to use QLF™ to assist in endodontic treatment. Using an ingenuous rotating optical fiber, inspection of an opened root canal could be inspected quantified for the presence or absence of RF. Although these results were promising, this is not yet possible with the currently available clinical QLF™ systems, mainly because the illumination cannot be concentrated sufficiently on the root canal under observation.

### Sealants and secondary caries

Sealants and restorations must not leak. With current standards it is difficult and often impossible to determine whether the quality of the margins is compromised before serious damage has occurred.

Because porphyrins tend to accumulate in the defective margins of sealants and restorations, QLF™ shows these defective margins quite clearly as can be seen in the images below.



**Figure 15.** (images courtesy of Karen van Daelen, SWT-TN).



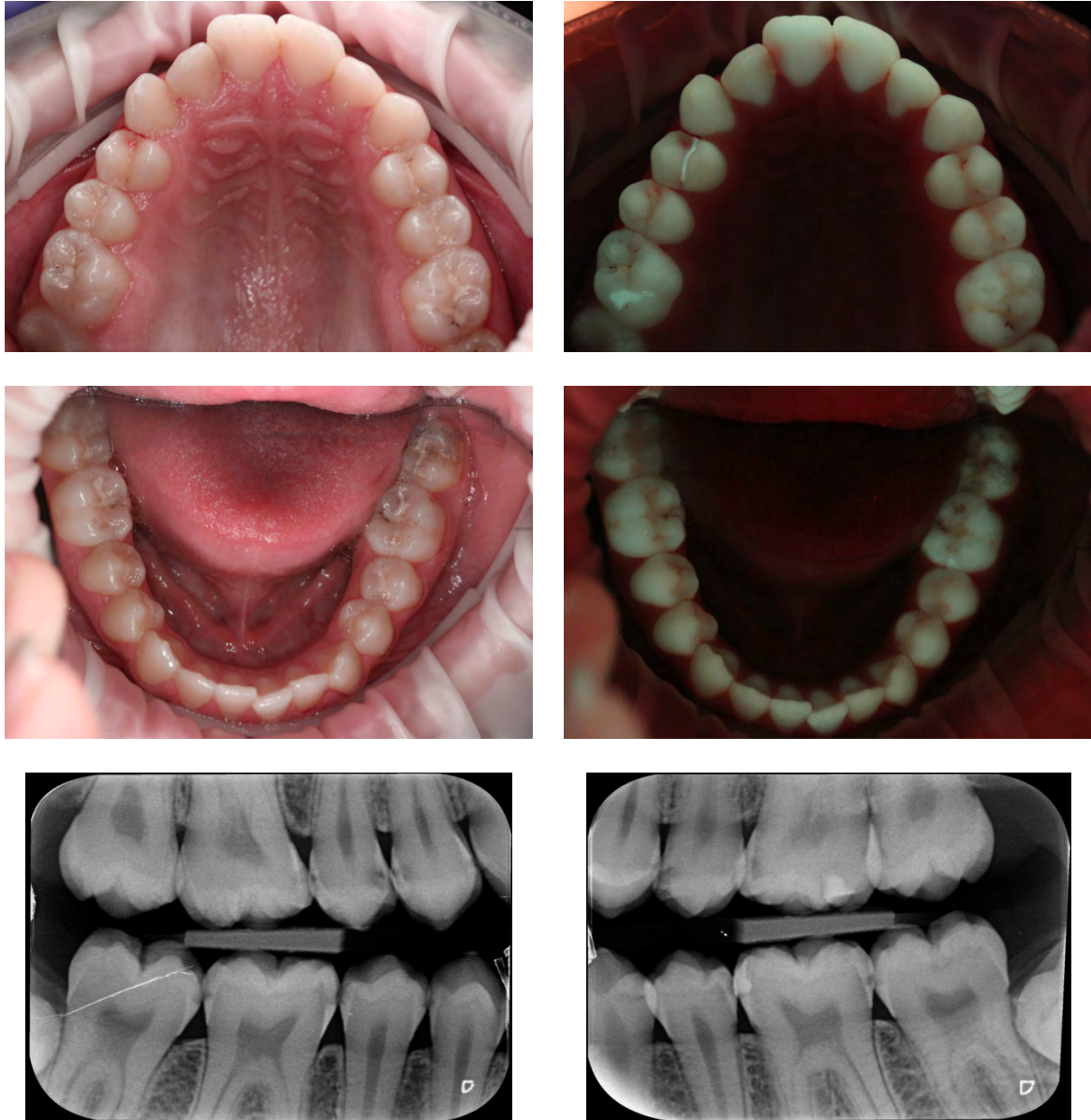
**Figure 16.** Example of secondary caries. The QLF™-image shows a lot of RF along the margins of the fillings. The left of the two central elements shows demineralization in combination with RF extending from the filling margin at the lower end of the surface (images courtesy of Karen van Daelen, SWT-TN).

### **‘Hidden’ caries**

The term ‘hidden’ caries is defined here as caries that develops under a seemingly sound surface. The most common example is approximal caries.

Recent clinical findings (see Figure 17) show that QLF™ can help to detect these lesions. Generally, detection of these lesions with QLF™ is used as an indication to make an X-Ray of the area to confirm the lesions and to estimate its size.





**Figure 17.** Two approximal lesions are identifiable in the white-light image of the upper mandible (elements 21 and 26). With the help of the QLF™-image, elements 15, 14, 13, 11, 21, 22, 24, 25, 37, 36, 35, 34, 44, 45, 46 and 47 also show signs of approximal caries. This was confirmed on the X-rays (*images courtesy of Karen van Daelen, SWT-TN*).

### **Patient motivation**

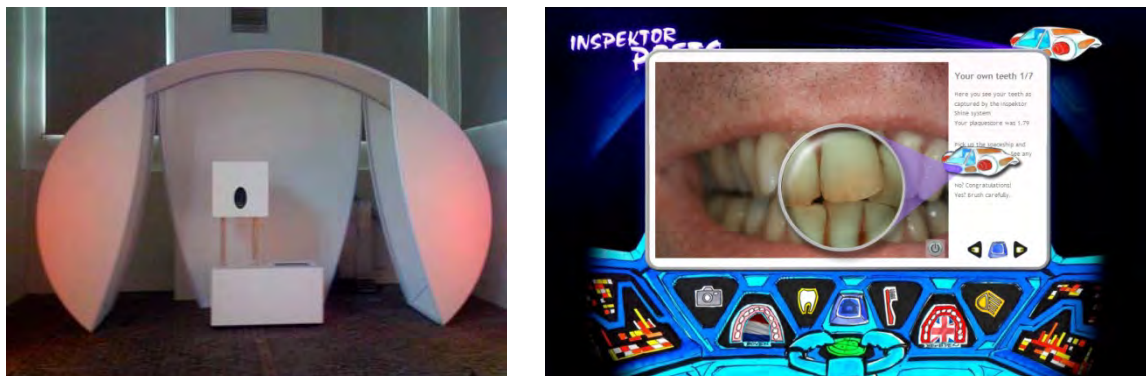
An underrated aspect in the past research on QLF™ has been the effect of its use on patient behavior and the relationship between practitioner and patient.

Almost all practitioners that have used QLF™ in a clinical setting have remarked on the fact that patients have a keen interest in their QLF™-images, are generally happy to discuss what they see and are quick to locate most of the issues themselves.

Experience in Tilburg shows that the time needed to make the pictures is easily compensated by the time gained in the explanation of the results and obtaining compliance of the patient with the proposed treatment [see Appendix 1]. Patients on the whole seem to prefer discussing the state of their teeth and oral hygiene in front of a screen to lying in a chair and just hearing about it or to looking at their mouth through a handheld mirror.

Because of the clearer contrast between sound and less-sound areas, their natural curiosity generates questions that quickly focus the discussion to what should be done.

Another proof of the positive effect of the use of QLF™ was the success of the QLF™ On-Line towers at the Boerhaave Science Museum in Leiden, NL, in the dental bus for epidemiological dental research of the Dutch Research Institute TNO during the 3FM Serious Request event in Leiden, NL, both in 2011, and during the ‘Nationale Gezondheidsbeurs’ (National Health Fair) in Utrecht, NL in 2012. The various implementations are shown in **Figure 18**.



**Figure 18.** On the left the Inspektor Shine installation at the Say Cheese exposition in the Boerhaave Science Museum, Leiden, Netherlands. On the right the page of the Inspektor Shine website where visitors could review the images they made.

Following the simple instructions on the screen, visitors could fill in a short questionnaire about their background and tooth brushing habits and enter their e-mail address. After positioning themselves in front of the camera two pictures (white-light and QLF™-image) were made.

From these pictures a plaque-score was derived and plaque score and corresponding oral hygiene advice was presented on the screen.

The images and score were also sent to the specified e-mail address and were also available on a special website (<http://www.inspektorshine.com>).

In the six months of its duration the exposition in the Boerhaave museum drew 20.000 visitors with a high percentage of schoolchildren (>15%) and the system was used, unattended, more than 6000 times, resulting in more than 12.000 images. The website was visited by more than 500 visitors.

An example of these images is shown below in **Figure 19**.



**Figure 19.** Examples of the pictures made with the QLF™ On-Line installation at the Boerhaave Science Museum in Leiden, Netherlands. From left to right, top to bottom: good oral hygiene, plaque, Ortho+good oral hygiene, ortho+plaque, calculus, RF on gingival region of false tooth.

### ***Economic aspects***

Apart from the fact that a technology provides added value and can practically be integrated in the often finely tuned logistics of dental health care, one of the deciding factors is its economic value.

Like any new technology, development is expected to continue and new hard- and software will emerge relatively fast.

For the clinical market therefore, the following scenario is proposed:

- The system is leased to clinicians. This includes hard- and software for taking image-sets, e-mail support and updates when new hard- and software becomes available.
- The lease fee is based on the number of image-sets taken and stored (pay-per-view) with a certain minimum and a basic fee.

To get optimal results in its use as a quality indicator for dental treatment, the following protocol is proposed:

All patients:

- For each new patient a full set of all possible views is taken (lateral left and right, frontal and extended, occlusal upper and lower mandible, lingual upper and lower mandible and optionally the tongue) along with visual inspection and X-rays.
- For each patient the same full set of all possible views is taken at each control visit, standard twice a year. X-rays are limited to once every 3 years unless indicated by QLF<sup>TM</sup> or visual inspection.
- For each patient that is to be professionally cleaned, image-sets are taken for 3 views (later left and right and extended) before the cleaning. Taking the same views after the cleaning is optional.
- When a patient changes to another dentist or clinic, he or she should be given the most recent full set of views taken as a reference and provide that information to the new dentist or clinic.

Orthodontic patients:

- For each patient that will start an orthodontic treatment, a full set of all possible views is taken (lateral left and right, frontal and extended, occlusal upper and lower mandible, lingual upper and lower mandible).
- Orthodontic treatment will not start when the Simple Plaque Score averages above 1. In that case the patient will be given oral hygiene instructions and be given a new appointment in about 3 weeks time to be examined again.
- During orthodontic treatment, a full set of all possible views will be made every 4 months.
- If during orthodontic treatment the Simple Plaque Score averages above 1, the patients are given oral hygiene instructions and be given a new appointment in about 3 weeks time to be examined again.

- If the patient consistently fails to bring down his Simple Plaque Score this is considered a strong indication for stopping the orthodontic treatment.
- At the termination of the orthodontic treatment, after the removal of all orthodontic appliances and a professional cleaning, a full set of all possible views is taken.
- This last set is used to determine whether or not additional preventive treatment is needed to repair any damage caused by the orthodontic treatment.

If this protocol would be used on a substantial scale, the cost of one image-set (a white light and a QLF<sup>TM</sup>-image) is expected to be € 0.50 or less.

Of course the cost of personnel, most often the prophylactic assistant, equipment and office for the duration of 2-5 minutes has to be added, although the same amount of time (or even more) would certainly also be necessary if 'standard' controls would be performed.

When special arrangements are made, such as mounting brackets for the system and viewing screen at the chairs or the installation of a special room for making QLF<sup>TM</sup>-images, the cost for these installations has to be brought into the equation too of course.

Clinicians using QLF<sup>TM</sup> claim these costs are easily made good because of higher productivity and improved patient compliance.

On the immaterial side they claim substantial diagnostic benefits for the dental professional and a significant increase in customer satisfaction.

Tests that have compared production on days where QLF<sup>TM</sup> was used for every patient to days where QLF<sup>TM</sup> was not used did indeed show a significant rise in production but these data as yet do not provide conclusive proof.

However, even if the benefits claimed may be viewed with some skepticism, it is clear that the investment in the integration of QLF<sup>TM</sup> in a financially sound dental clinic should pose no great financial difficulties.

## ***Conclusions***

Based on research and clinical experience, there is little doubt that the introduction of QLF<sup>TM</sup> into daily dental care can benefit both patient and dental professional.

It significantly improves the ability of the dental professional to document, identify and monitor the state of health of the oral cavity and individual tooth elements visually, reproducibly and quantitatively.

It provides the dental professional with a very powerful tool in the communication with the patient, especially on the subject of prevention and oral hygiene. This reduces the time needed for explanations and instructions and improves the patient's compliance with the proposed treatment plans.

From patient's point of view, all experiences to date show a universal acceptance and keen interest in the QLF<sup>TM</sup> results.

Perhaps the most important aspect of QLF™ is that its introduction automatically includes the use as an evaluation instrument for treatment decisions.

QLF™ is the first technology that allows dental professionals, scientists and industry to justify their treatments, preventive as well as restorative, and to evaluate the results of these treatments objectively and in much greater detail than ever before.

Finally, integration of the technology in the daily practice is not only practically but also economically feasible.

### ***Recommendations***

More research is needed on the fundamental aspects of the technology, especially concerning the red fluorescence. The reasons for the empirically found relation between its presence and pathology should be explored and explained.

Linking the presence or absence of red fluorescence to the actual composition of the biofilm would be a very interesting subject.

In parallel, clinical validation should be the main focus of clinical research. The work of Allamari *et al.* that provides practical and quantitative guidelines for the assessment of QLF™-images should be confirmed, refined and, if possible, extended.

The retrospective work of van Daelen, that compares diagnosis of early caries with and without QLF™ to the longer term outcome, should be complemented with more carefully controlled, prospective research.

The effects of QLF™ on patient compliance and motivation should be tested in double blind studies comparing effects of feedback using QLF™ images and analysis data with standard inspection and feedback.

At the same time, QLF™ opens many new avenues of research. The ability to monitor teeth and individual elements and element-surfaces opens up a whole new field for the development and evaluation of preventive and restorative treatments.

Also the link between the existence of red fluorescence and periodontal diseases has been noted but is still not understood.

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## **Appendix 1: Reference letter SWT-TN**

Tilburg, September 29 2011

Dear colleague,

I would like to share some of my QLF experiences with you.

Prevention is considered one of the most important key points in dental practice. Good patient motivation is most necessary in order to conduct and maintain good dental hygiene. Unfortunately it can be a real struggle.

By using the QLF-D system we can now show our patients their level of dental hygiene and follow up the overall compliance by making new images on a regular basis without using any disclosing solutions which are experienced as tedious by many patients. Besides that it stains our sinks and is hard to remove from the equipment or clothes. QLF-D clearly shows the areas which need more attention by means of brushing and/or interdental cleaning. Images speak louder than words.

When patient compliance enhances, our job becomes easier. All our orthodontic patients receive QLF-D treatment from the moment we start fixed orthodontic equipment like brackets and this is repeated every 3 months until orthodontics are finished. When the level of dental hygiene is insufficient, we increase the number of hygiene appointments, by letting them visit every 3 weeks. In this way we can maintain a better control of the patient's compliance and whenever the level of hygiene cannot be improved, QLF gives us suitable measurements to preliminary withdrawal orthodontics. Also parents are most supportive about us using QLF imaging. Dental benefits are gained due to data storage and follow up through time possibilities.

We also use QLF for dental diagnostics. QLF-D shows dark areas whenever decalcifications are present and a light orange color is to be seen when there are lesions. Also interdental lesions can be seen in some cases. Especially in circumstances where we doubt the possible outcome of a clinical diagnosis, QLF can be of excellent service to obtain more information. QLF TC is a perfect tool for this. Quicker than the QLF-D images and perfect during restoration.

QLF can also show its use when we are to check the cavity. Especially QLF TC with the goggles is a very pleasant tool to quickly and by excellent vision, show if the lesion is ready to be filled.

We have looked at how we could make a good financial model and what we know now is that every day use of QLF repays the camera within about a month. Taking into consideration the costs of the dental chair, dental nurses, hygienists and the camera itself. We are thinking about incorporating another QLFD system in 2012.

I hope I have given you some more information about our experiences here.

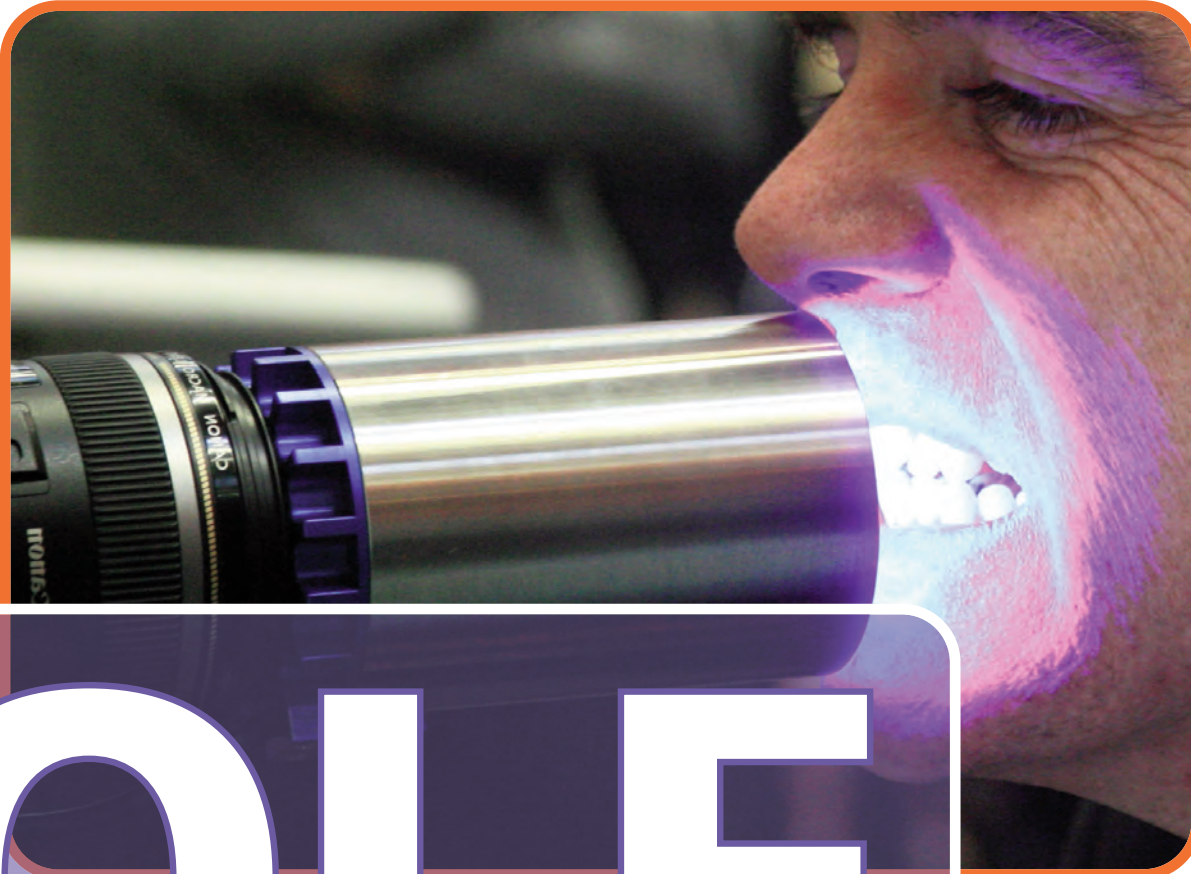
Jan Van Loock, dentist, chief of staff

Graduated in Gent, Belgium, '78

Cooperate Dentists, Tilburg-North, The Netherlands

# QLF-D BILUMINATOR 2

## AWARD WINNING TECHNOLOGY



# QLF

- Image and analyse bacterial activity (red fluorescence) with QLF:
  - in plaque
  - in calculus
  - in enamel
- Image and analyse white spots with QLF (green fluorescence)
- Compare white light and fluorescence images
- Monitor oral health longitudinally
- System includes QLF Research Software



- State-of-the-art In Vitro Research setup

**NEW:**  
Integrated model,  
fixed or mobile



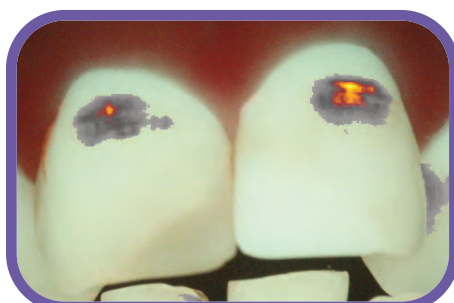
White light  
(normal) image



QLF image



Colour-coded  
analysis of  
QLF image



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