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Thermography, an imagistic method in investigation of the oral mucosa status in complete denture wearers

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In order to evaluate thermography in exploring the oral mucosa of denture wearers and dentate subjects, a pilot study was conducted where two mobile denture situations and a dentate one were analyzed using infrared thermography. Numerical values corresponding to the thermograms showed an increased temperature underneath prostheses with different distribution in oral mucosa, corresponding to the clinical picture. Thermography can be a non-invasive procedure to assess the oral mucosal status in denture wearers, which can provide important information on prevention, diagnosis and treatment of oral diseases.

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1. Introduction

The complete edentulous is a clinical situation that occurs after losing all teeth, present especially at elderly. The most used treatment methods consist in the insertion into the oral cavity of mobile prosthesis pieces from polymeric materials, for restorative reasons, through complete conventional or implant supported dentures [1]. Several studies detected a modified mucosal status within patients that wear polymeric mobile prostheses, integrated to the pathological entity defined as "denture stomatitis" [2-6].

The etiopathogeny of the disease reveals factors of prosthetic order, due to the polymeric material and the microbial factor (frequently Candida). As result of the fact that complete denture wearers belong mainly to elderly patients, often with deficient immunity and multiple general pathology, with poly-medication and effects of salivary flux reduction, the risk of denture stomatitis appearance increase in this population group [7, 8]. An important aspect in installing oral mucosal lesions, a factor that shouldn't be ignored, is the temperature increase under the acrylic denture, fact that favors the saprophyte microbial flora pathogenisation and its toxic action [8, 9].

The diagnosis for denture stomatitis (DS) is generally established clinically and often found out by chance, after a routine consult. This is caused by a limited and unspecified symptomatology for denture stomatitis, frequently the patient having no complaints. The clinical data can be correlated with the paraclinical ones (especially the microbial exams), simple procedures can be chosen, with more or less rapid, respectively sensitive results, and also some more complex ones, with more specifications and higher costs.

In this article, the authors intend to evaluate the possible use of thermography in establishing the oral mucosa status in denture wearers, also, to achieve correlations with some clinical situations with pathological changes, starting with normal clinical aspects. The exact hypotheses were:

- If and in which way can infrared thermography be used (by indicating the local thermal surface variations) as a direct diagnosis method or a secondary one for the pathological changes of the oral mucosa, as early diagnosis or predisposition?
- How can the results of this method be used by the prosthodontist in increasing the dentures quality, prophylaxis of the support tissues, but also in monitoring some treatments or oral diseases?

2. Medical thermography

2.1. History

Ever since the 2nd century BC, Hippocrates visualized the local temperature measurement value for medical diagnosis, making early thermographic experiments [10], deeper documentations begin then from the 4th century BC [11]. The target measurement, the quantity one, was possible only at the mid-18th century, with the development of the thermal scales Fahrenheit, Reaumur and Celsius. As a medical procedure, thermography was first introduced in 1956 by R. N. Lawson for breast cancer diagnosis.

2.2. The method's principles

Medical thermography is a method used to measure surface temperature of various parts of the body, closely related to local metabolism, the physiological and pathological changes of various tissues underlying the changes in flow sanguine [11]. The skin temperature is about 5° lower than body temperature. The level of skin temperature is determined by vascular offer, the vascularisation degree of skin tissue (venous blood) and underlying tissue metabolism. Pathological processes, and also their evolution are materialized by a change in surface temperature and can thus be easily diagnosed, monitored respectively, being a possible indicator of inflammation.

Body heat is released at the skin level in the form of electromagnetic radiation invisible to the human eye, but can be collected and processed by special detectors, such as a sensor sensitive to infrared radiation.

The basic principle for assessment by thermography consists in symmetrical temperature distribution hypothesis for both sides of the body to a healthy subject. Thermograms of a patient are assessed comparative to the results of an evaluation conducted in a healthy subject for 40 areas of the body (belonging to both the right and the left half of it in a symmetrical and equal way). Differences of up to 0.2°C can therefore be detected and a difference of 1°C above the corresponding healthy body surfaces is considered significant in terms of disease. Investigated patients are deprived of any exposure to radiation.

2.3. Thermographic methods

In current practice, there are several thermographic methods. Some of them are:

- Liquid crystal thermography

It's a contact thermography, in which the examined body part is placed on a slide that is saturated with cholesterol esters. Cholesterol esters are active from the optical point of view and change color within a predefined temperature interval and changes are recorded with special sensors.

- Infrared thermography

It's a thermography method relatively recent, used for around 30 years. Due to the advantages it offers, its field of use is expanding rapidly, given the development and diversification of equipment, in conjunction with the development of portable computers, specialized programs and detectors array that don't require conventional cooling systems, specific to military technology [12].

The photographic camera with infrared records computerized thermograms with maximum precision. With special sensors, thermal camera transforms thermal radiations, as radiations emitted in the infrared spectrum, invisible to the human eye and issued by any living organism, in electrical pulses (electromagnetic). They can be processed in real time by a computer.

The advantage of the method lies in its accuracy and that can be performed without direct contact. Infrared thermography as a method for noninvasive examination, however, presents a number of limitations: high cost of installation; high qualification of the operating personnel, as interpreting the results requires complex knowledge, often interdisciplinary; ways of detecting changes located just near the studied surface [12].

- Stress thermography by inducing low temperature

Investigated tissue is cooled by a cooling stimulus (such as placing hands in cold water). Subsequently thermal uniformity values of the area are recorded with an infrared camera. Thermoregulatory capacity may thus provide information about existing pathological processes.

2.4. Medical fields of application of thermography have increased numerically in recent decades due to progress registered in the image processing techniques, the sensibility growth of thermal sensors and spatial resolution. Infrared images provide a useful approach, passive, non-invasive and painless for diagnosis, prognosis, and also treatment monitoring of general affections, particularly in the areas of rheumatology, dermatology, endocrinology, oncology, orthopedics, cardiology, neurology [11], where thermography has gained a large proportion. Comparatively low in applicability compared to general medicine, there have been conducted studies in dentistry, also records, some with reproducible results in endodontics [13, 14, 15, 16, 17, 18], odontology [19], TMJ disorders [20, 21], OMF surgery [22, 23], dental anesthesiology [24] and implantology [25].

3. Pilot study on thermography, exploring the oral mucosa in denture wearers

In order to evaluate the thermographic method in exploring the oral mucosa of denture wearers, a pilot study was conducted, in which thermography as a method of investigation was experimented.

3.1. Material and methods

In order to achieve the objectives, the pilot study was divided in 3 stages:

- Stage 1: inclusion of 3 subjects with different clinical aspects of oral mucosa.
- Stage 2: oral mucosa analysis by thermographic investigation.
- Stage 3: analysis and thermographic data conjunction with the clinical ones.

In the first phase, three patients with different clinical aspects present in the oral mucosa were identified by clinical means, aspects considered representative:

1. dentate subject, clinically healthy, with the oral mucosa without pathological changes, without dentures;
2. complete bimaxillary denture wearer with Newton I DS;
3. complete bimaxillary denture wearer with Newton II DS.

Newton I DS is characterized by localized inflammation, reduced in intensity. Pinpoint hyperemia, red lenticular spots, of needle whole size corresponding to the inflamed salivary glands is present [26]. In Newton II denture stomatitis the mucosa fixed on the support shows diffuse erythema. Congestive areas are restricted to within mucosa that comes into contact with the polymer denture base [8].

Furthermore, the patients were informed about new methods of investigation and their informed consent was obtained.

In stage two thermographic investigations of the maxillary oral mucosa were carried out in all subjects. Thus infrared camera ThermaCAM PM 350 (Fig. 1) was used, from the FLIR range system, Inframetric's. Characteristics of identification and interpretation (processing) elements of the device used are presented in Table 1 and Fig. 2.

Thermographic equipment characteristics used in this study:

Thermography in the field of mobile prosthodontics is a new, interdisciplinary method. The authors didn't find any literature references concerning its use in the investigation of the oral mucosa in denture wearers, particularly in denture stomatitis. This implies the need to underline certain concepts of terminology used in thermography, as follows:

Infrared thermography is a technical procedure that allows obtaining, using a proper device, the thermal image of a thermal scene observed in a field of infrared spectral range. By thermal image we mean a structured distribution of representative data of infrared radiation from a thermal stage, and by thermal stage a part of the space-object that is observed with infrared thermography equipment.

Thermographic examination is an observation, measurement and interpretation of thermal scene characteristics using a set of devices and instruments called thermography system.

Thermography system refers to all devices that allow receiving and processing a thermal radiation image.

The thermogram is a result of the transcription in temperature of one or more maps of luminance (luminance - brightness of objects measured in cd/m^2); a coded image of a thermal scene.

Emissivity or emission factor is a dimensionless number with values between 0 and 1, representing the ratio between the total power emission of a certain body and the black body.

The black body is a perfect body that fully absorbs the received thermal radiation, also being the best transmitter [27].

Table 1. Identifying elements of the device.

Characteristic	Values
Image enlargement	2:1, 4:1
Sensitivity	< 0.1°C
Digital Resolution	12 bits, 4096 levels, 72 Db
Detector	PtSi/ CMOS 256 × 256 FPA
Spectral band	3.4 – 5 μm
Temperature Range	-10 … 450°C
Maximum temperature measured (with filter)	1500°C
Black and white and color image	256 – levels on the grey scale, 9 color palletes
Operating temperature range	-15 … +50°C
Storage area	-40 … +70°C
Voltage / frequency	95-250V / 47-63 Hz
Power required	6 V cc., < 12W
Camera dimensions	210 × 114 × 90 mm
Camera weight	1.7 kg
Total weight (Including battery, lens and color viewfinder).	2.7 kg

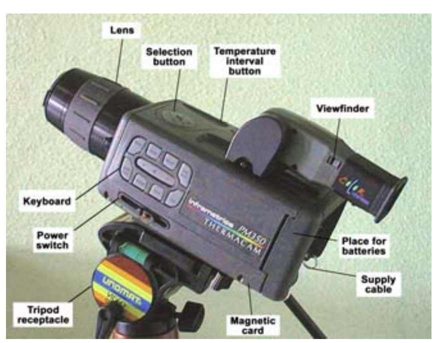

Fig. 1. Portable infrared camera ThermaCAM PM 350.

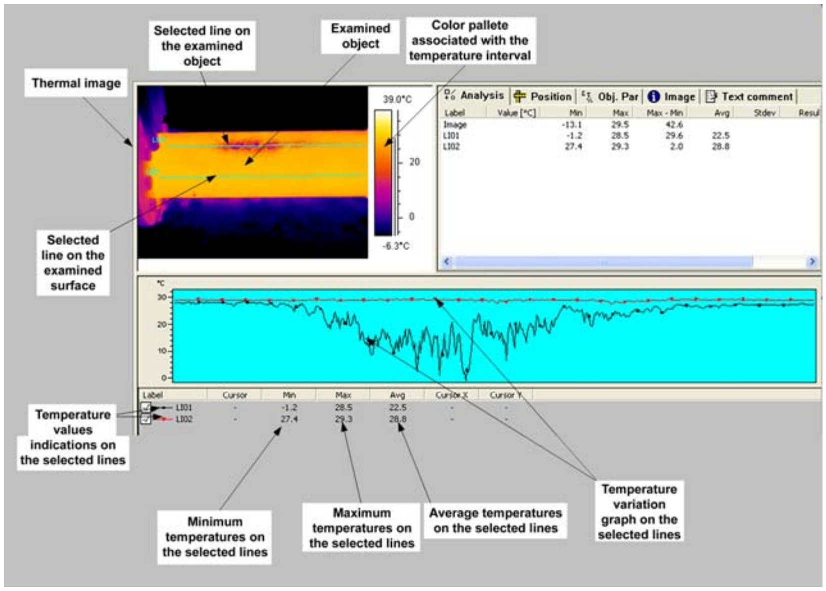

Fig. 2. Identification and interpretation elements (processing) of a thermographic image.

In order to obtain valid results the following implemented procedural requirements were considered:

- Room temperature in which investigations were conducted was uniform, constant throughout the procedure, keeping in within the range of 20-24°C.
- Humidity ranged from 45-60%.
- Before the thermography, subjects weren't exposed to particular thermal conditions (such as physical exercise, exposure to sunlight).
- 24 hours before the thermography procedure subjects didn’t receive treatments such as acupuncture, electrotherapy, ultrasound or anti-inflammatory drugs.
- It was established to exclude nicotine consumption, alcohol, coffee and tea, in the procedure day.
- The subjects were asked not to drink/eat anything 60 minutes prior to the procedure.

The investigation was carried out with the subjects sitting down, with adequate support for the cephalic extremity [28]. Before the thermography, an automatic calibration of the thermal camera was prepared. Due to the cooling system of the camera, the time it takes for it to work and auto-calibrate is about 10 minutes. The following parameters were set manually (manual calibration stage):

- Choice of emission specific to the human body, respectively $\varepsilon = 0.98$ [27]
- Humidity
- Environment temperature
- Color palette
- Manual focus of the image
- Use of the temperature interval -10°C and 65°C.

Thermographic examination started 30 minutes after the presentation of the subjects in the room, during which they were provided with accommodation to the ambient temperature. Also, subjects were asked not to lean themselves against other objects that could influence body heat (chair, wall, etc.). Sterile oral plastic cheek retractors were applied, and both dentures were removed in total edentulous subjects.

Fig. 3. The thermography stage.

Parameters related to emissions, distance to the investigated areas was set in the configuration menus of the infrared camera. Then thermal scanning with ThermaCAM PM 350 camera of the oral mucosa followed, with the objective oriented at an angle of 70° from the palatal vault plan, from a distance of 25-30 cm between the front lens of the camera and the examined area. Scanning itself took about 2 minutes. The detector was cooled with an integrated microsystem that operates on the Stirling principle (with helium pump) [12].

Thermographic images are presented along with the visible images, to be able to correctly identify the interest areas. The color palette is associated with a range of temperatures. The thermography camera is able to 'seize' automatically minimum and maximum values of the thermal scene. These values are associated with a corresponding color palette and the information is presented as thermal images. These are obtained by converting heat (thermal radiation) in temperature values. Thermal images were taken with the thermocam and stored on a PCMC card in TIFF format specific to the ThermaGram software, for specialized analysis and interpretation, optimizing the temperature range used, adapted to the color palette.

Examination by the authors is focused on two aspects: one is clinically visible, the other, associated thermally. The data were presented as images point by point, without a mechanical breakdown of the object image. The images were subsequently transferred, but in the same session to the computer for viewing, analyzing, processing, and storage respectively. Thermographic investigation undertaken by the authors, materialized as thermograms of the mucosal surfaces, contain images on which the warmest points were indicated, that may be of practical interest.

In stage 3 were comparatively analyzed the three clinical situations (a normal status, two complete denture wearers, with pathological aspects of DS) and related thermograms were correlated with different clinical aspects.

4. Results and discussions

The color palette on thermograms is associated with a range of temperature. Through the parallel assessing of thermographic images and those visible (Fig. 4, 5, 6, 7, 8, 9), with the identification of interest areas, we could observe the following aspects:

1. The obtained thermograms show different images for different clinical situations. Thus:

- At the mucosa of clinically normal aspect, the dentate subject, a young female patient (Fig. 4), which has not been in contact with polymeric bases, the thermal field distribution on the surface of the maxillary oral mucosa at the palatine vault level was uniform (Fig. 3), with an average temperature of 36.1° C. These values, as can be seen, correspond to red color in the thermal image. In the same subject, overall, low thermal variations were found.

- At the mucosa with DS type Newton II, of the elder subject with complete dentures, emphasizing clinically (Fig. 7) areas of congestion (especially on the ridge, subjected to higher pressures), as physiopathological phenomenon resulted from the relationship with polymer prostheses, the image was completely different. The thermal field was uneven (Fig. 6), with an average temperature of 36.6°C for edentulous ridge areas, respectively 35.5°C for the palatal vault mucosa. A thermal value registered for the ridge surfaces with congestive mucosal phenomena, respectively flabby ridge aspect, corresponds to the yellow color in thermal imaging, as thermal maximum. Also we found differences in the thermal field color distribution that belong to the two halves right/left of the examined mucosal area.

- In mucosa with DS type Newton I, at an elder male wearing complete dentures, the thermogram presents differences compared to both the first, as well as for the second investigated subject. Erythematous areas, punctiform, clinically localized at the mucosal palatal vault level (Fig. 8) correspond thermographically to the yellow area (thermal maximum), allocated to an average temperature for that area with the value of 36.6°C (Fig. 9). Other mucosal areas, clinically with a normal aspect, show much lower heat values than the area mentioned above, especially in frontal areas of the edentulous ridge with thermal average intervals of 34.6°C on the left side, respectively 35.1°C on the right side. These low heat values are reflected by the green color of the palette. The thermogram in this subject shows variations of thermal field distribution in much higher percentage compared to the second investigated subject, respectively to the first one.

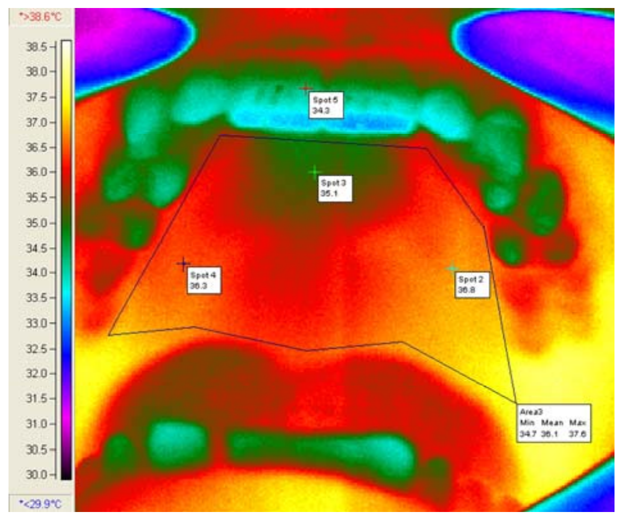

Fig. 4. Mucosal thermogram at the dentate subject.

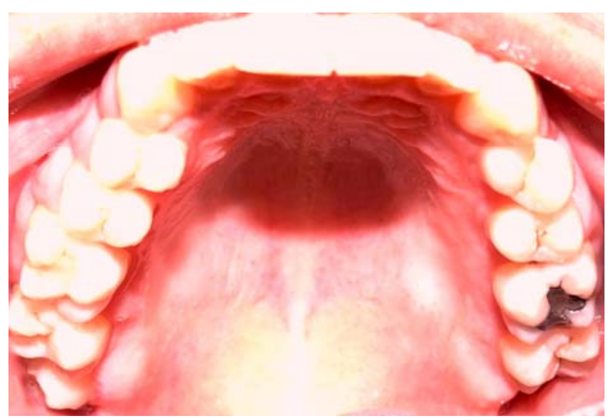

Fig. 5. Clinical picture at the dentate subject.

2. Deduction of a possible correlation between clinical appearance of the mucosa, prosthetic behavior and thermograms, with elevated temperature in patients with dentures compared with the ones without.

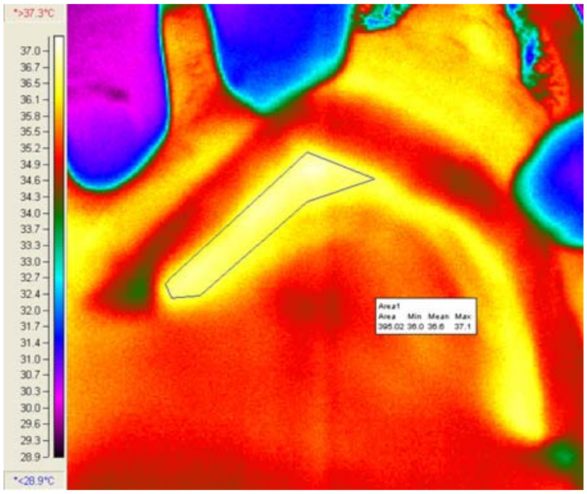

Fig. 6. Mucosal thermogram in DS type II.

Fig. 7. Oral mucosa with DS type II, clinical aspect.

3. On the other hand, the possibility of clinical pathologic correlation phenomenon with a particular aspect highlighted by the thermogram, by the presence of the polymeric dentures, a higher occlusion pressure to the ridge, congestive mucosal phenomena in relation to the denture.

Technical development, rapid and ample, of the infrared thermographic cameras, opens new perspectives for their use, not only in general medicine area, but also in dentistry. In particular, thermography can be used by the prosthodontist in planning the treatment with full dentures, for mucosa investigation, pathological processes of mechanical or infectious-inflammatory origin, presented under the polymeric bases.

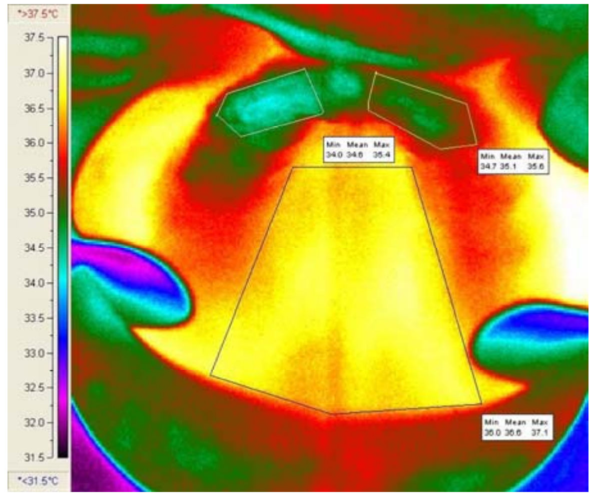

Fig. 8. Mucosal thermogram in DS type I.

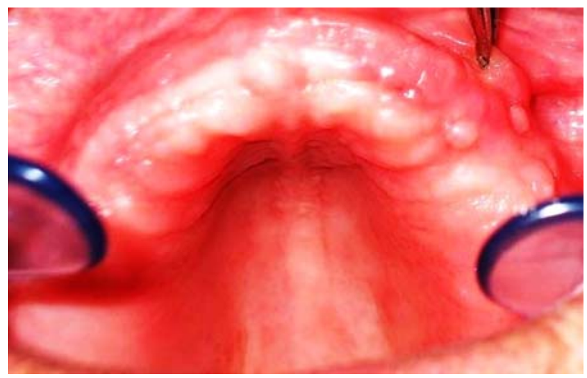

Fig. 9. Oral mucosa in DS type I, clinical aspect.

Infrared thermography of the oral mucosa presents a series of advantages that derive in the particularities of the method:

- Within the experiment no consumables or instruments were needed, other than those necessary for a routine dentist consult.
- The thermographic equipment consists of the infrared camera, with size and weight comparatively equal with a usual camera, the software mentioned before, and a computer.
- The method is absolutely noninvasive, nonpainful, and also it lacks noxiousness. The thermographic images (thermograms) were registered from a distance, without immediate contact with the subject or the examined surface.
- Because of bidimensionality the resulted thermal images (Fig. 4, 6, 8) offer the possibility of comparing the surfaces of interest and their analysis.
- Time allocated to each thermographic scan made in this study was extremely short; the order of seconds, the thermal images could be visualized and analyzed immediately after storage in form of thermograms of the interest areas.

Being a pilot study, we can't say that all the data referred to this investigation method of the support mucosa in denture wearers have been exhausted, but through ulterior studies we can enlarge and specify its area of use.

As perspective studies, we can thus predict new evaluation possibilities of the oral mucosa changes, with preventing value through early detection of lesions, or the quantification of their gravity, treatment efficacy, with the value of a more precise exam than a simple clinical evaluation.

5. Conclusions

At the end of the presented study the following conclusions can be reached:

1. Thermography can be used as an evaluation method of the temperature under the dentures, with effects upon the oral mucosa status in completely edentulous patients.
2. Temperature changes observed when using thermography can be interpreted from the quality point of view, as placement and intensity of the pathological phenomenon, but also from the quantity point of view, referred to the dimensions and the position of the investigated surface.
3. The method requires a clear vision upon the technical aspects of the thermography, but also of its limits.
4. This investigation method can be correlated with anatomical, morphological, physiological and phisio-pathological aspects from of the oral structures in completely edentulous patients with complete dentures.
5. Thermography can be correlated with pathological changes of the oral mucosa in relation with the acrylic denture base. This can be useful in preprosthetic diagnostic stages, in establishing an etiological diagnosis of the pathology in the support oral mucosa, but also in monitoring the prosthetic or antimicrobial treatment.
6. Thermographic evaluation, as an investigation method of the oral mucosa in complete denture wearers, opens the way towards ulterior research, which the authors intend to do in the future.

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