Investigation of artificial tooth morphology using a holographic interferometry technique

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A surface morphology of artificial tooth is investigated using a holographic interferometry, whereby a virtual three dimensional image is captured on hologram film using a 633nm He-Ne laser. Image of artificial tooth morphology is produced by using optical reconstruction from virtual image, and then captured by a digital camera. It is found that the optimum angle for capturing the virtual image is 90^0 and it is not possible to produce high quality images using a camera with resolution of 5 megapixels. With the use of a high resolution camera of 10 megapixels, a clear image is captured with sufficient intensity for the interference fringe. This shows that a holographic interferometry technique can be used in conjunction with a 10 megapixel camera for dental imaging in obtaining tooth morphology documentation.

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1. Introduction

The study of functional dental morphology has gained much interest due to the prevalence of fossils that are represented only by their dentition and the desire to interpret them in order to learn about an animal's mode of living [1]. The importance of dentition to the nutritional ecology of an animal is also reported in many literatures [2-4] and thus more information can be gained from the relationship between morphology and the action of teeth. Medical instruments such as digital radiography, video imaging, x-ray radiography and computer tomography are usually used for dental imaging. These instruments produce dangerous ionizing radiation that may cause abnormal and loss of cell functions [5]. Thus, many efforts have been made to design an alternative diagnostic apparatus that are accurate with minimum side effects using a non-destructive, non-invasive, non-ionization method. An alternative imaging technique to measure dental morphology is the holographic interferometry [6-9].

Holography follows a different principle from conventional photography. A laser is needed to produce a coherent, monochromatic light beam. The difference in phase between a reference ray and the object ray (to be analyzed) produces an interference pattern that is recorded on a high-resolution photographic plate (hologram). When developed and suitably exposed to laser light, this hologram reconstructs a three-dimensional image of the object. Resolution is that of the order of the laser wavelength or that of a photographic film. This technique has a very high accuracy, which can detect optical track difference as small as one light wavelength. This method is non-destructive and usually used to study temporal changes in diffusion process, vibration and movement of plants. It also can be used to capture artificial biology samples such as bio-implant heart and bio-prostheses.

In this paper, surface morphology of artificial tooth is investigated using a holographic interferometry. A virtual image of in-vitro artificial tooth is captured on hologram film using a He-Ne laser. The three dimensions imaging of holographic interferometry is an effort to assess the surface wear of the tooth, which is very important in dental applications.

2. Experimental details

There are two important processes involved in this holographic interferometry method: recording and reconstruction processes. Fig. 1 shows an experimental setup for the recording process, which consists of a He-Ne laser with a shutter, a beam splitter, a mirror, lenses, an artificial tooth and a holographic film. Highly coherent, 633 nm He-Ne laser with output power of 1 mW is used in the experiment while a high-resolution film (AGFA - Holotest 8E75 - 5000 lines/mm; AGFA Corporation, Ridgefield Park, NJ, USA) is used to capture the image. Laser beam is split by the beam splitter to produce reference and object wave-fronts. The object beam illuminates a tooth under investigation and is reflected to the holographic film. At the same time, the reference beam hit the mirror. The reflected reference beam interacts with the object beam to produce hologram on the film. All components were secured on an optical table buffered by compressed air in order to avoid vibrations. A shutter with electronic exposure control was used to control the exposure time. The experiment was carried out in a totally dark, draft-free environment. The experiment is initiated by preparing the research material such as artificial acrylic tooth sample and also set up of track optical alignment. Laser beam were properly aligned and the beam noise is cleaned using pinhole. The path distance difference between the reference and object beams is adjusted to be within the coherence length of 20 cm. The sample is exposed to the laser within 5-7 s during the recording step.

Fig. 2 shows the setup for the reconstruction process, which consists of the same laser, beam splitter, two mirrors, objective lens, a digital camera and a computer. The holography film is processed to become hologram by immersing it into a developer solution (mini-grain) for about 5 minutes in a dark room. The film is then cleaned using water and is shivered for 2 minutes for neutralization. It is then transferred into acidic solution for another 5 minutes. Finally, the film is washed by flowing water over it for about 10 minutes and dried using a hairdryer. In the optical reconstruction process, the hologram is illuminated with the reference beam. Beam is scattered by the hologram to form an illusion shadow of three dimensions from the backside of the hologram. The Resulting virtual image is captured using a digital camera (Canon A640 10 Megapixel and Samsung S500 5 Megapixel) at the optimized angles of 80^o and 90^o. The digital images are then analyzed based on the intensity profile using Matrox Inspector 2.1 software to investigate the artificial acrylic tooth morphology. The morphology obtained from the reconstruction result is compared with the real image of artificial tooth photo, which was captured using the same digital camera.

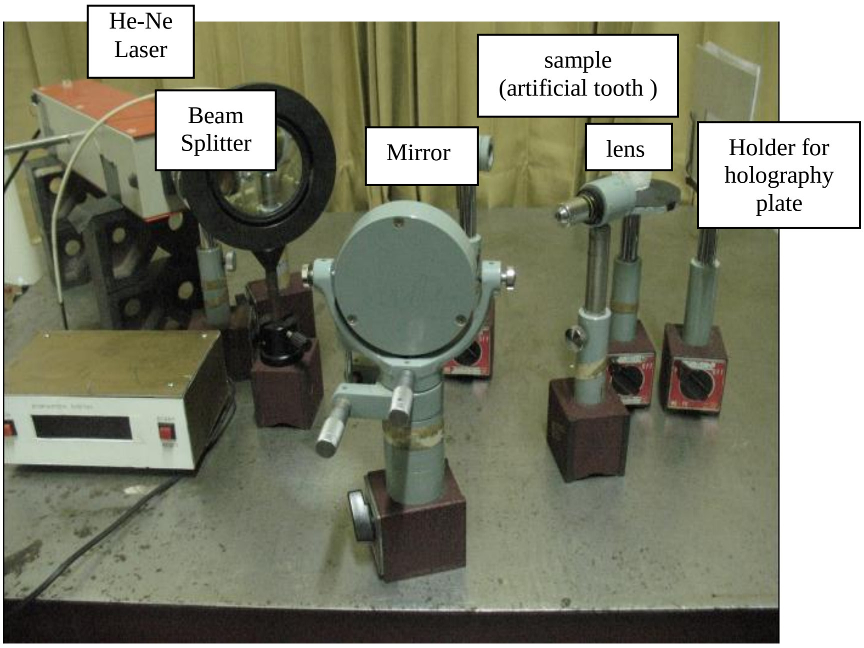


Fig. 1. Experimental arrangement for recording process

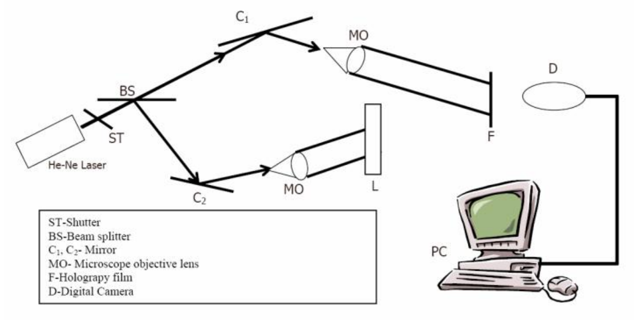


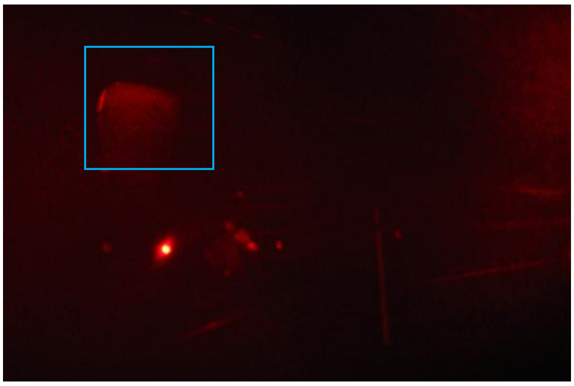
Fig. 2. Experimental setup for reconstruction process.

3. Result and discussion

A virtual image of the second incisor artificial tooth is produced by holography technique. Figs. 3(a) and (b) show the image captured by two different digital cameras with 5 and 10 Megapixel resolutions, respectively. Fig. 3(c) shows the actual image of the artificial incisor tooth captured by the same digital camera. It is observed that the virtual image cannot be properly captured by a lower resolution camera of 5 Megapixel. Fig. 4 shows the image captured from two different angles; 80^o and 90^o. From comparison, it can be seen that 90^o is the most optimized angle for capturing the virtual image.

Fig. 5 shows the intensity profile along the image where (a) and (b) represent the profile of 10 and 5 megapixel images, respectively. The red color line represents the intensity of the interference fringe from the hologram. It is observed that the intensity is so much higher with the use of higher resolution camera of 10 Megapixels. In the higher intensity image, the intensity variation is more significant and obvious and thus it is suitable to be used to determine the dental surface morphology. Due to lower resolution, the 5 megapixel image is blurry and can only detect the beam noise as shown in Fig. 5(b). It is also found that the performance of the recording process is strongly dependent on the optical devices. In this work, the objective lens with magnification of more than 20 times should be used in conjunction high intensity He-Ne laser. A higher quality image is expected to be achieved with the use of digital image processing or filtering technique. This result shows that holographic interferometry in conjunction with a 10 megapixel camera can be used in dental imaging for obtaining tooth morphology documentation.

a



b

c

Fig. 3. Images of the artificial tooth from a digital camera (a) virtual image with 5 megapixels (b) virtual image with 10 megapixels (c) actual image.

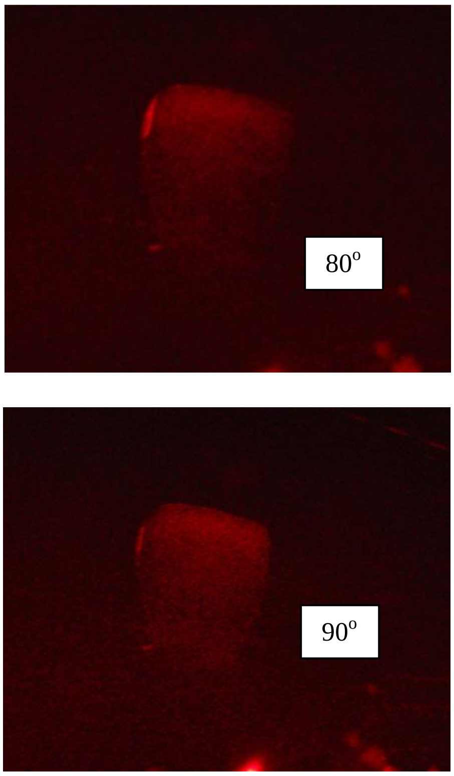


Fig. 4. Virtual images captured at 80° and 90°

Fig. 5. Intensity profile along the image for (a) 10 megapixels (b) 5 megapixels images.

4. Conclusions

A virtual three dimensional image of artificial tooth morphology is captured using a holographic interferometry technique. In optical reconstruction process, image of artificial tooth morphology is produced from virtual image, and then captured by using a digital camera. A 633nm He-Ne laser is used as a light source in both processes. It is found that the optimum angle for capturing the virtual image is 90^0 and it is not possible to produce high quality images using a camera with resolution of 5 megapixels. With the use of higher resolution camera of 10 megapixels, a clearer image can be captured with so much higher intensity of the interference fringe. It is shown that a holographic interferometry technique can be used in conjunction with 10 megapixels camera for dental imaging.

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