Comparing the eFinger and the finger to measure the stiffness of the \textit{ex vivo} prostate gland

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Abstract. The development of prostate cancer is accompanied by an increase in tissue stiffness within the gland. This is often measured clinically using a digital rectal examination (DRE) where the gland is palpated using a finger. A dynamic instrumented palpation (DIP) device (the eFinger) has been developed to instrument this process. In an initial proof-of-concept of the device, it is compared to palpation examination in the \textit{ex vivo} prostate gland. Initial findings show the sensitivity of the device may exceed that of palpation examination, allowing the identification of non-palpable tumours.

Introduction

Changes in stiffness in the prostate gland are related to the development of disease such as prostate cancer or benign prostate hyperplasia (BPH) \cite{1}. DRE has been used to screen for prostate cancer on this basis. However, it is a subjective technique with low sensitivity. DRE also uses a static palpation to assess tissue quality, which misses many attributes of tissue that could be better examined using a dynamic approach. As a first step to improving or supplanting DRE, we have developed a DIP device \cite{2} to assess tissue quality in the prostate \textit{ex vivo}.

Experimental methods

Sensor/actuator. The sensor/actuator (the eFinger) is made up of layers of acrylic sandwiched together. The upper layer has a membrane made from a flexible silicone material with an embedded strain sensor (Fig 1). The membrane is dynamically inflated and deflated using a compressed air supply and the air pressure is measured using an in line pressure sensor. The membrane is placed on to the surface of the prostate and actuated. Changes in the dynamic strain behaviour of the membrane are related to the stiffness of the prostate gland at that position.

![Figure 1. An eFinger. The membrane (with embedded strain sensor) is at the far end of the device.](image)

![Figure 2. An excised prostate held on the xyz measurement stage.](image)

Patient cohort. Patients with prostate cancer scheduled for radical prostatectomy (the complete removal of the prostate gland via minimally invasive surgery) were recruited for this study. Ethics approval was granted by the local research committee.

Prostate samples. Each prostate was intact after surgical removal. Within 30 minutes of removal, the prostate was taken to the laboratory and stiffness measurement was carried out. The prostate was placed on an xyz measurement stage (Fig. 2) and a systematic array of measurements were made on the posterior surface at 5mm x and y spacings. The posterior surface was measured since it is the only one accessible \textit{in vivo} through the rectal wall, and the majority of cancerous tissue is found on that side of the gland. An \textit{ex vivo} palpation examination was also carried out by a urologist to identify locations where stiffer areas could be felt. The same locations were palpated digitally as were measured using the eFinger and were graded as shown in Table 1.
**Histology.** Immediately post-measurement, the prostate was sent for histology examination. Whole prostate slices were made at locations corresponding to each row of measurements made using the eFinger (Fig. 3). The tissue in each slice was stained (Fig. 4) and classified using the Gleason grade [2].

**Measurement method.** Two measures of stiffness were used to compare eFinger measurements with palpation examination. For both measures, the membrane strain (ε) and the pressure of the air supply inflating the membrane (P [Pa]) are used. The amplitude ratio, defined as

\[ AR = \frac{\hat{\varepsilon}}{\varepsilon} \]  

represents the dynamic stiffness response of the tissue. The mean ratio (MR), defined as

\[ MR = \frac{\hat{P}}{P} \]  

represents the quasi-static stiffness response of the tissue. These were compared to *ex vivo* palpation to assess whether the eFinger measured stiff regions in the same locations as a palpation examination.

**Results**
A comparison of *ex vivo* palpation with eFinger stiffness measurements is shown in Figure 2.

**Discussion**
From inspection of Fig. 5, the eFinger has identified an area of increased stiffness (in the AR graph) at position 14. This corresponds to the location of the tumour outlined there that was not identified using palpation examination. This shows that in some cases eFinger can be more sensitive than palpation in the *ex vivo* prostate gland.

**Conclusion**
Measurement of the stiffness of the prostate gland *ex vivo* with the eFinger has a higher sensitivity than palpation examination, and may also measure non-palpable disease.

**References**