

Knees & e-Sensors - wearables from a clinical perspective

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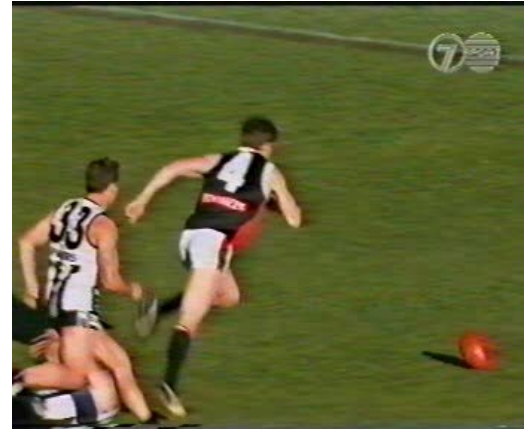


Outline

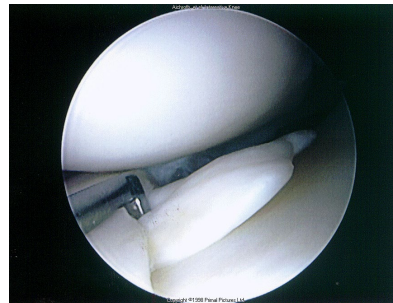
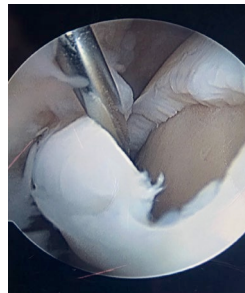
- What potential issues do I still have in 2024 ?
 - Knee Ligament instability
 - Wound Infection diagnosis
 - Periprosthetic Joint Infection diagnosis
 - Better Chronic (neurogenic / OA) pain management
- What do I (think I) need ?

Knee Ligament Injury

- Anterior Cruciate Ligament (ACL)
 - Common injury > 15,000 / year in UK
 - Contact injuries largely unavoidable
 - Non-contact injuries MAY be preventable



- Devastating in young
 - Commonly associated with chondral & meniscal pathologies
 - Invariably leads to early onset degeneration & accelerated osteoarthritis within 20 years



What Assistance Do I Need Today ?

- 1. Unable to predict who will rupture their ACL pre-injury ... despite screening sports persons & established injury prevention programmes (FIFA 11+)
 - More common in young females - Hormonal laxity / muscle activation lag theories
 - Biomechanical & anatomical 'predictors' of likely rupture = landing from a jump / valgus / ER position ...aswell as high posterior tibial slope / lateral knee hypoplasia ...



What Surgery, On Whom & When ?

- 2. Who needs surgery = Unable to predict 'copers' (15%) vs 'non-copers' (85%)
 - Often reconstruct all young / sporty patients ... based of 'risk of further instability' without actual proof
 - to prevent further joint injury when the knee gives way
- 3. What operation to perform - who needs additional surgical reconstruction techniques ?
 - Simpler isolated ACL reconstruction vs addition of complex extra-articular tenodesis surgery



- 4. Unable to provide 'personalised' rehabilitation programme
 - Treated all the same in terms of standard rehabilitation and advised to avoid return to sport for 12 months

What I really need ... an e-brace to determine

- Analysis of *in vivo* sports biomechanics / muscle activation / joint position / forces ... to intervene when multiple risk factors occur (eg. alert on watch when muscles tired / protective reactions compromised)
 - = intervene pre-rupture
- Real- time analysis of point of injury = what went wrong and when ?
- How to predict the 'copers' ... and avoid un-necessary surgery
- What operation does each patient actually need ?
- Personalised physiotherapy / bracing to accelerate return to function
 - both a return to work (£) / social & professional sports



Phil's Pivot-Shift-o-Meter



- Knee Sleeve (neoprene)
- Embedded smart sensors and power source
- Wireless interface to smart-watch with app development
- Continuous monitoring ability
- Big data analysis
- Cheap – to permit mass screening in schools / colleges / sports teams

(Slight) potential drawbacks to my plan !

- Highly complex biomechanical & EMG analysis with large data set likely to be generated
- Inter-leg & inter-person biomechanical variability (different combination of risks in each patient and different biomechanics once ACL deficient)
- Rehab : Different surgical techniques (not all operations are equal)
 - Graft type (hamstring / BPTB / quads tendon +/- augmentation)
 - Surgical tunnel positioning / graft tension variability
 - Concomittant chondral / meniscal / ligamentous injuries specific to each injury
 - Unique personal anatomy / muscle lag / risk factors in each case

Infection : e-textiles & electronics

1. Superficial wound infections

- Surgical wound covered by impervious occlusive dressing post-op for 2/52
- Diagnosed clinically when dressing removed (or later when patient at home)
- Often well established (chronic) at point of diagnosis
 - Wound breakdown / sinus formation
 - Requires physical mechanical debridement +/- repeat surgery (£)
 - MUCH easier / cheaper / safer to treat earlier ... if only we knew about it !
- Hence I need a preclinical accurate diagnosis
 - Infection (yes/no) & causative organism

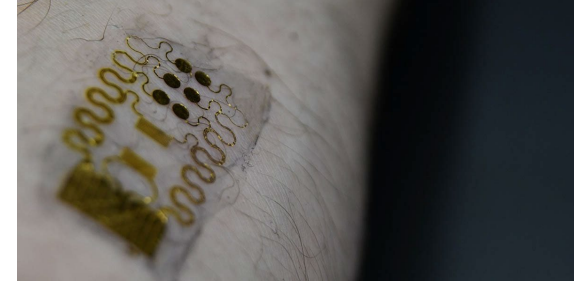


Earlier Diagnosis Vital = easier to treat

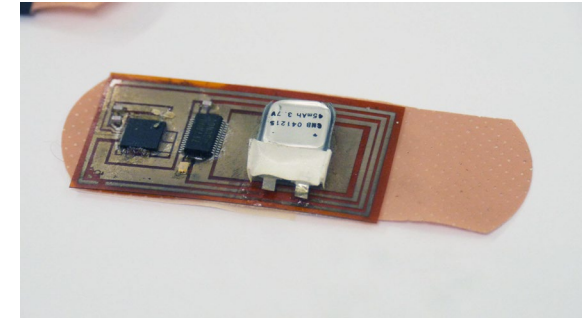
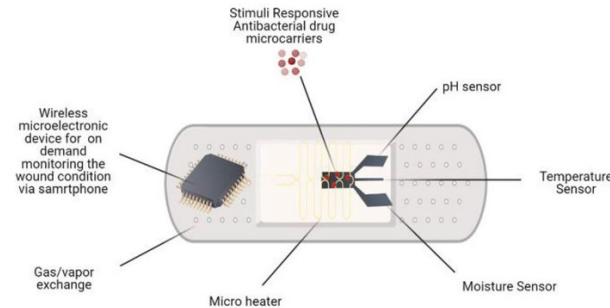
- Bacterial / Fungal infection = associated with necrotic tissue
 - Volatile Organic Compounds (VOC) = specific odour given off
- pH = acidosis
- Increased wound lactate / decreased glucose
- Decreased wound oxygenation
- Increased wound vascularity / localised swelling
- Temperature
- Increased exudate (moisture) produced



E-nose dressing +



- Impervious e-dressing (isolating the wound environment)
- Electronic nose sensor with capability to isolate different VOC associated with specific bacterial strains (Staph / Strep / E.coli etc)
- pH / lactate etc
- Temperature
- Oxygen saturation
- Blood flow
- Swelling
- Moisture content

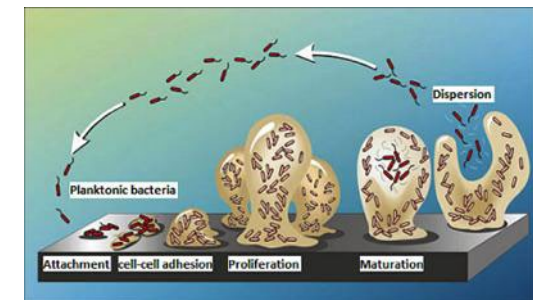


- Ability to wirelessly upload to smart-watch app to enable a pre-emptive / pre-clinical diagnosis to be made which is predictive of impending clinical infection
 - alerts healthcare team / books outpatient nursing clinic review whilst activating remote drone home delivery of suitable antibiotic (based on specific bacterial infection and medical record allergy)



2. Periprosthetic Joint Infection (PJI)

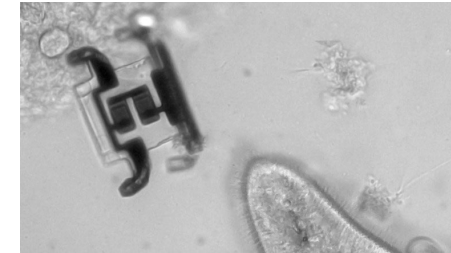
- Occurs 1-2 % joint replacements
- Known patient risk factors = comorbidity / known surgical risk factors
- Often diagnosed late = harder to treat
- Difficult diagnosis (swelling / haematoma / pain / warmth all common post TKR) = same as infection
- Suspected with persistently elevated inflammatory markers
 - CRP always elevated 2-3 weeks post-op so less helpful
 - Diagnosis relies on aspiration of joint (microbiological analysis to culture organism)
- BUT : Bacterial colonies produce protective biofilm (after 24 hours)
 - Bacteria adherent to prosthetic implant surface
 - Hidden under biofilm making accurate sampling (aspiration) difficult
 - Microbiology = no growth in >10% cases = missed diagnosis
 - Chronic infection > 3 weeks often needs more complex open debridement surgery +/- removal implant



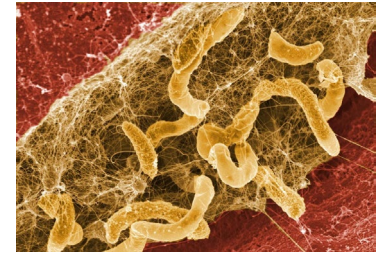
Nano / Microbot Diagnostic & Therapeutic Potential

- Small (?) 1-2mm bioabsorbable (?) nanobots
- Injected into intra-articular cavity in large numbers
- Able to control motion and hence direction of travel
 - Magnetic / ultrasonic / other propulsive power ??
 -
- Able to mechanically breakdown biofilm as they move across / round the joint = enabling more accurate aspiration sampling with higher numbers of planktonic bacteria
- Able to (either be retrieved from joint or) ideally breakdown spontaneously within synovial cavity without detriment to TKR or intra-articular biological structures
- If used to 'treat' PJI then they could both mechanically breakdown / disrupt the biofilm and secondarily deliver high dose local antibiotics incorporated into structure or polysaccharide capsules / bubbles – released over prolonged periods

Actual mobile nanobot



Mature biofilm



Chronic (Neurogenic) Post TKR Pain

- 20% TKR patients are dissatisfied with results of surgery
- Majority have true mechanical pain
- Some 1-2% have neurogenic / Complex regional pain disorder - only 'managed' by strong opiate based painkillers / anti-nerve medications both of which have significant CNS side-effects
 - dose tolerance / addiction / sedation / dizziness / failure to concentrate
- Many patients cannot 'function' / work / drive
- Leads to high rates unemployment / reduced social functioning / poor sleep / psychiatric illness (depression / suicide)
- Further Surgery / Amputation generally makes pain WORSE
... hence very difficult to manage

Therapeutic Knee Pain Brace

- Prof Kai Yang and her multidisciplinary team at Southampton and Winchester Universities have developed what may be highly useful in such a scenario based on a therapeutic knee sleeve = wearable TENS machine
 - utilising the Melzack & Wall 'Gate Theory of Pain' to reduce pain and increase medication-free function and return to active life



Summary

- E-textiles may be a solution to ongoing problems we face :
 - Helping to prevent some ligament & chondral sports knee injuries
 - Assisting with correct surgical decisions based on data analysis
 - Permitting personalised rehabilitation to return to activity sooner
- Infection diagnosis : earlier and increased accuracy
- Smart-dressings could even be preloaded with encapsulated antibiotics
- Infection treatment : potential mechanical disruption of biofilms +/- delivery of high dose intra-articular antibiotics
- Pain management therapeutic garments

Thank you