Appendices

Appendix 1: Meniscus Contact Area

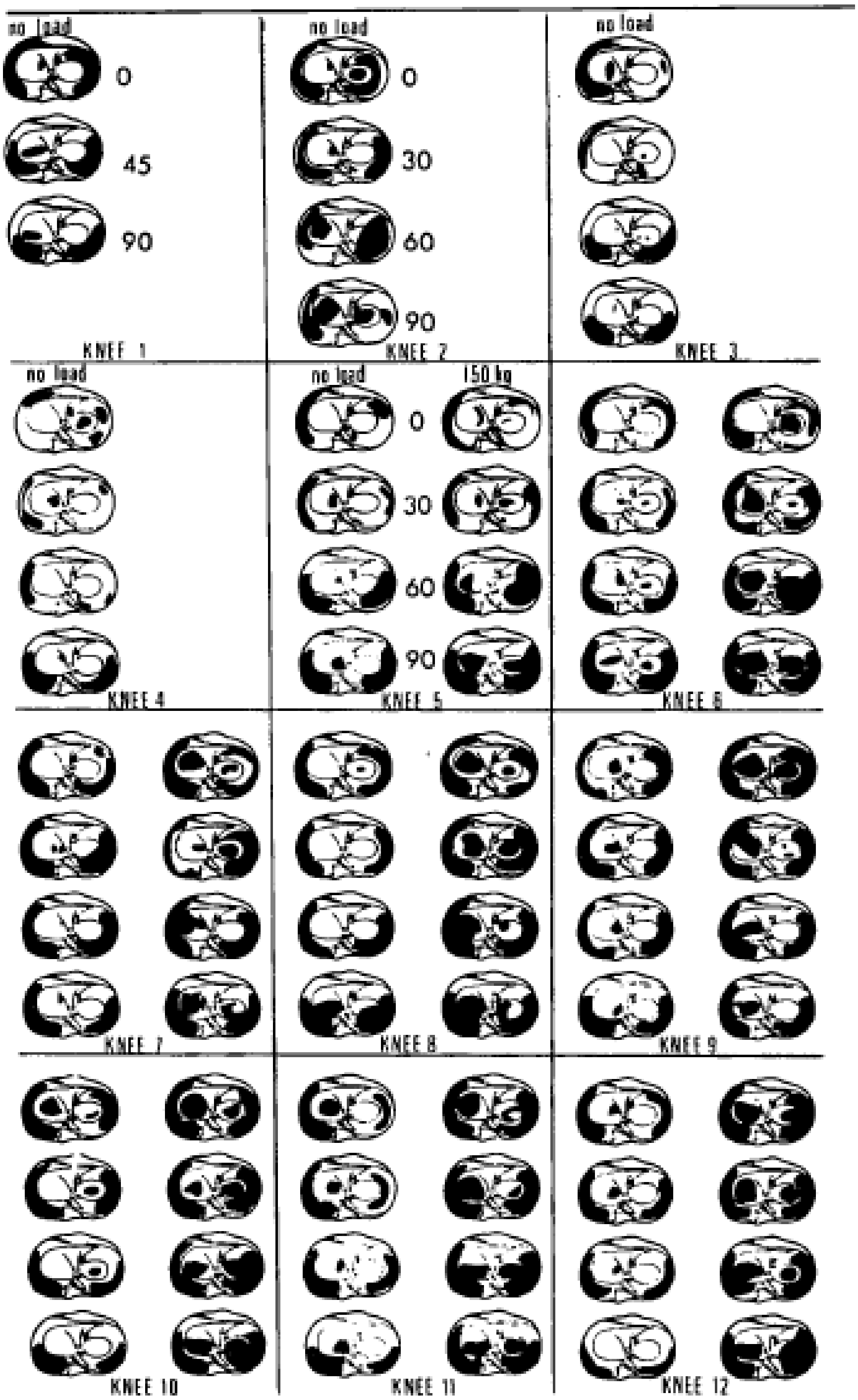


Figure from the 1975 Peter Walker et al paper[216]

Appendix 2: List of questions for the interview

First interview.

Find out a bit from the surgeon:

- What is your main area of orthopaedic surgery?
- Do you normally use an oscillating cutting saw (with or without navigation assistant) or a robotic burr head? And which is your preference?
- What areas do you think need to be addressed in orthopaedic surgery?

What are the Priorities for an Implant?:

- Choosing an implant model for a patient what are the factors that make you choose one over the other?
- If the above is cost or contract, if you were able to choose without either of these constraints, what would be the factors?
- Do you normally use an oscillating cutting saw (with or without navigation assistant) or a robotic burr head?
- What improvement would you like to see in implant technology?

About robot implants?:

- When using the burr to remove bone, what is the:
    - Easy part?
    - Advantage?
    - Annoying/awkward part?
    - Disadvantage?
- What, in your mind, would make using the burr head easier?
- How would you feel if an implant design requires changing the size of the burr head?

Shape and Style of Implant:

- In your experience, what shape of implant provides the best clinical outcomes

Where should the implant sit within the knee compartment

Appendix 3: MRHA reports on knee replacement - 2008-2016

January 2017

- Zimmer had manufacturing problem which lead to their Vanguard femoral component to be labelled incorrectly. This could lead to a delay in surgery to an early revision of the knee.

9 December 2016

- The Oxford fixed lateral bearing (UKR) had a batch of left bearing labelled as right bearing on the packaging. If it was noticed to be the wrong bearing it delayed the surgery for up to 30 minutes, if it wasn't noticed then it could lead to early failure of the UKR.

8 November 2016

- Mathys' balanSys UNI convex PE inlays with a thickness of 5m was recalled due to a high number of incidences that they failed ("breakage") at approximately 5 years.

7 July 2016

- MicroPort Orthopedics had a recall of all its hydroxyapatite (ADVANCE® HA) coated tibia bases because they were experiencing a high number of revision due to component loosening.

14 June 2016

- It was reported that 8 batches of the Smith & Nephew's LEGION HK prosthesis (revision TKR) did not have the CE mark on the outer label (but present in the inner label). There was association with adverse consequences but they still had a voluntary recall.

31 May 2016

- Stanmore Implants Worldwide Limited femoral plateau plate did not fit into the femoral knee assembly. This resulted in: an increase in surgery time, up to 15 minutes for all surgeries; potentially an increase in surgery time to 60 minutes (for some surgeries); and early failure due to the potential to loss cement integrity over time.

26 May 2016

- Smith and Nephew's LEGION HK femoral component inside surface failed to meet specification required for cement adhesion. This could lead to loosening of the implant to cement interface and potentially leading to a further revision surgery.

6 April 2016

- Biomet 360’s TKR was issued a correction. The augment are meant to be mechanically attached to knee otherwise the long crew lengths allow displace, up to 1mm but will not become detached.

4 March 2016

- Zimmer Biomet recalled RHK knee 16mm bearing because the some batches had been labelled with an incorrect numerical suffix.

25 February 2016

- Restoris MCK Baseplate’s packaging from Stryker was damaged, thus the product was not sterilised to the degree needed for surgery; this resulted in a delay in the surgery to collect a replacement device or the packaging damage was not noticed and was used which can lead to infection. Action was to check inventory and report back to Stryker.

January 2016

- Biomet’s Zimmer prostheses had packaging problem. The low density polyethylene bag, on occurrence it had been reported to adhere to the prosthesis. It wasn’t expected to have negative consequence if accidently implanted with the prosthesis but there was a potential it could delay surgery for up to 10 minutes.

18 December 2015

- Biomet had a packaging error, the NexGen Option Tibial Plate was miss-packaged in a NexGen Precoat Tibial Plate packaging. This either caused delay in surgery or lead to an early revision.

8 September 2015

- ConforMIS identify that certain batches potentially had a sterilisation problem that may have resulted in ethylene glycol residue. They offered a voluntary recall of effected batches.

30 and 29 June 2015

- The femoral components on Biomet's AGC dual articular 2000 and 360 prostheses (TKR) had a manufacturing problem. There was excess material removed from the patella flange edge. The action advised for patients implanted with the mistake prostheses is to have rest to allow healing.

29 May 2015

- Stryker recalled their Triathlon Tibial Bearing insert CS X3 Size #2 9mm because there was a misprint in the labelling.

23 March 2015

- Certain Biomet's Oxford cementless UKR lacked the required hydroxyapatite for encouraging bone growth. The report required hospitals to check their stock to see if they had the defective UKR and in all cases report back to Biomet.

March 2015

- DePuy required patients with their LCS Complete knee patella prosthesis to have their patella resurfaced.

14 October 2009

- DePuy's PFC Sigma cruciate retaining non-porous UKR: Size 5 femoral components were found to have a defect on the posterior chamfer region, resulting in a possible fracture of the device.

20 July 2009

- Stryker Orthopaedics's MRS Cemented Stems (for hips and knees): Some sizes were incorrect and were implanted into patients and are at risk at failure.

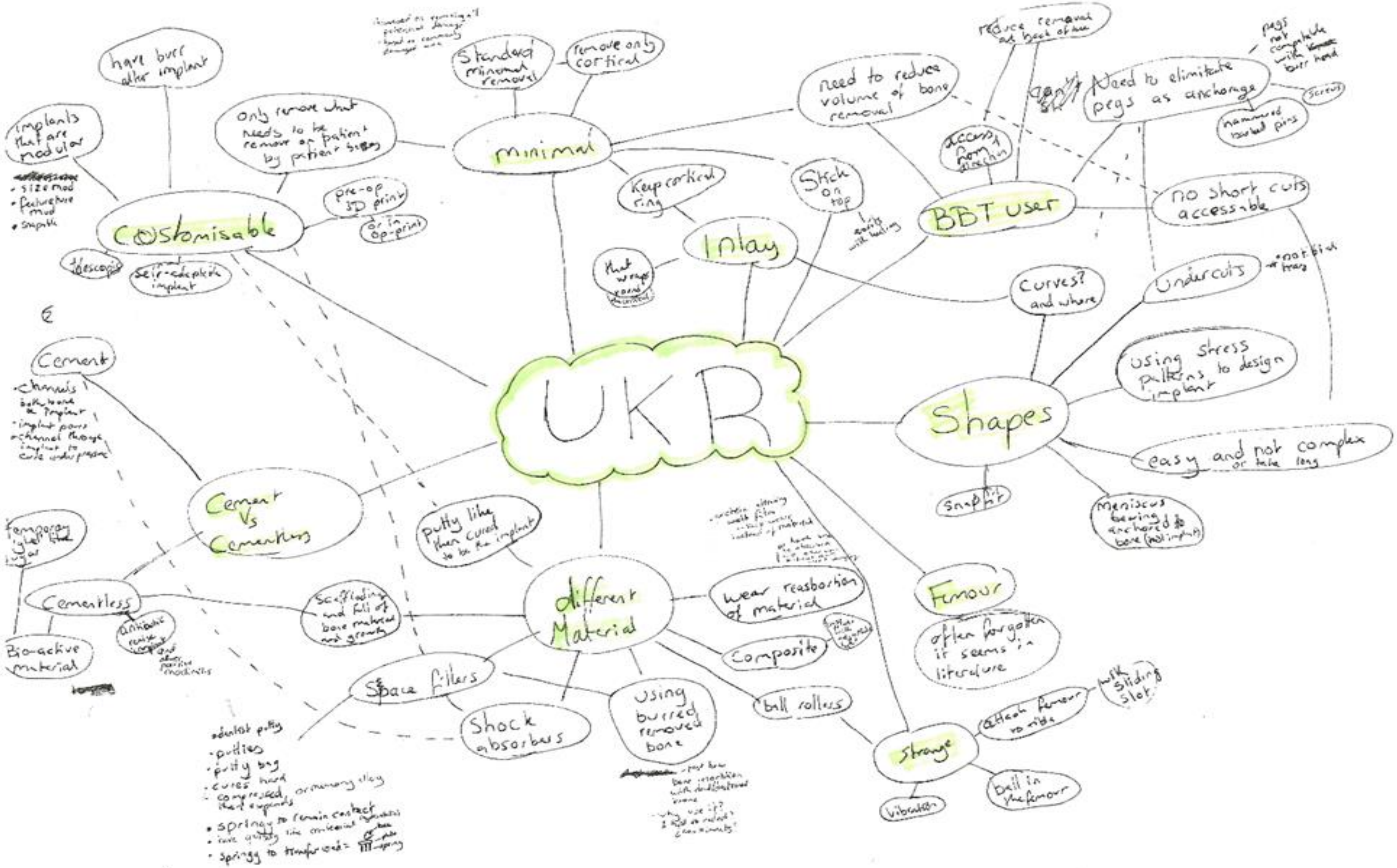
3 June 2009

- DePuy's mobile preservation unicompartmental knee has been noted to have a higher revision rate (failure modes reported to date include: loosening, pain, wear of the polyethylene component and early periprosthetic fracture). DePuy stopped advertising their mobile option and was discontinued throughout Europe from August 2009.

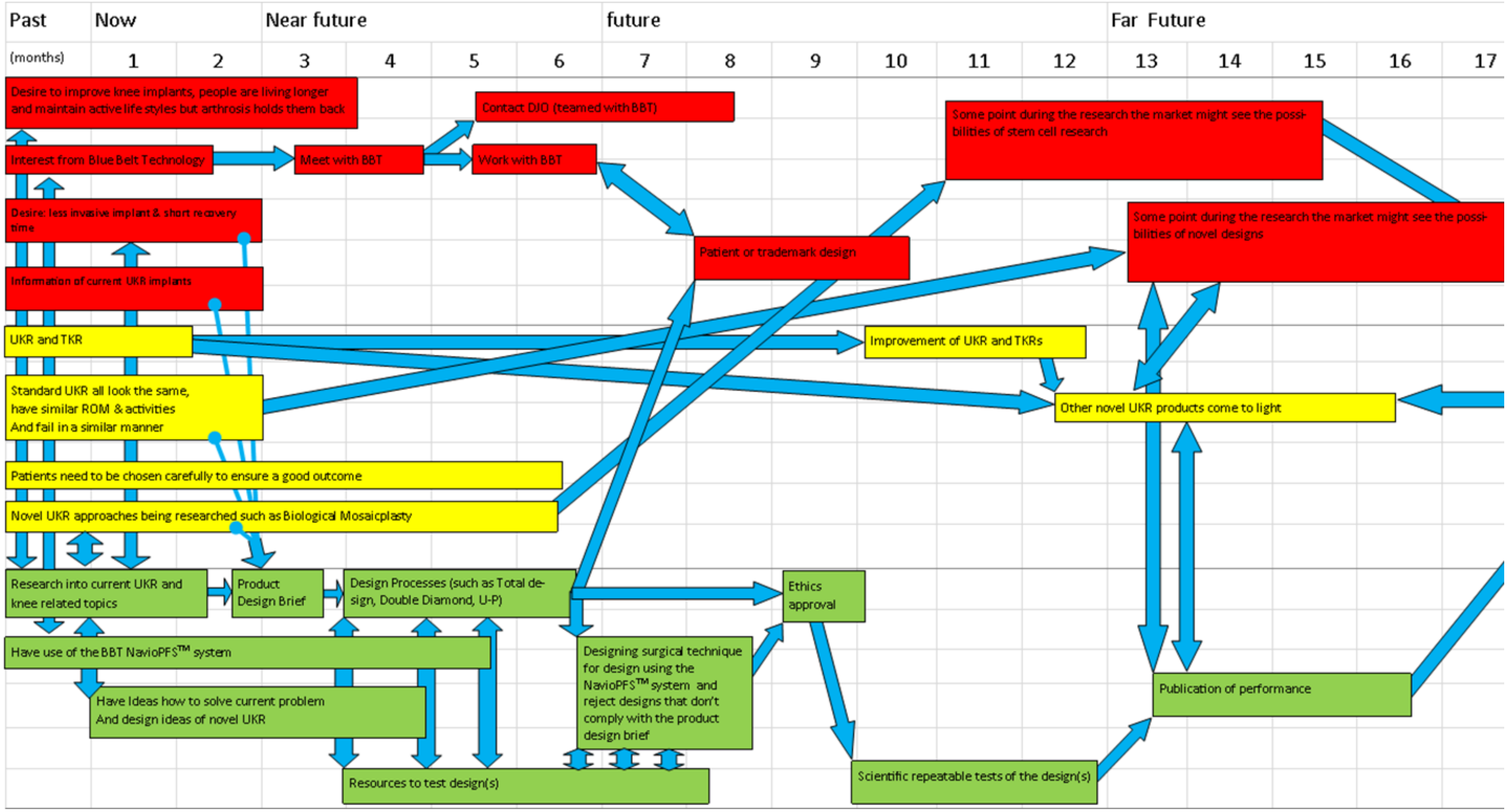
22 September 2008

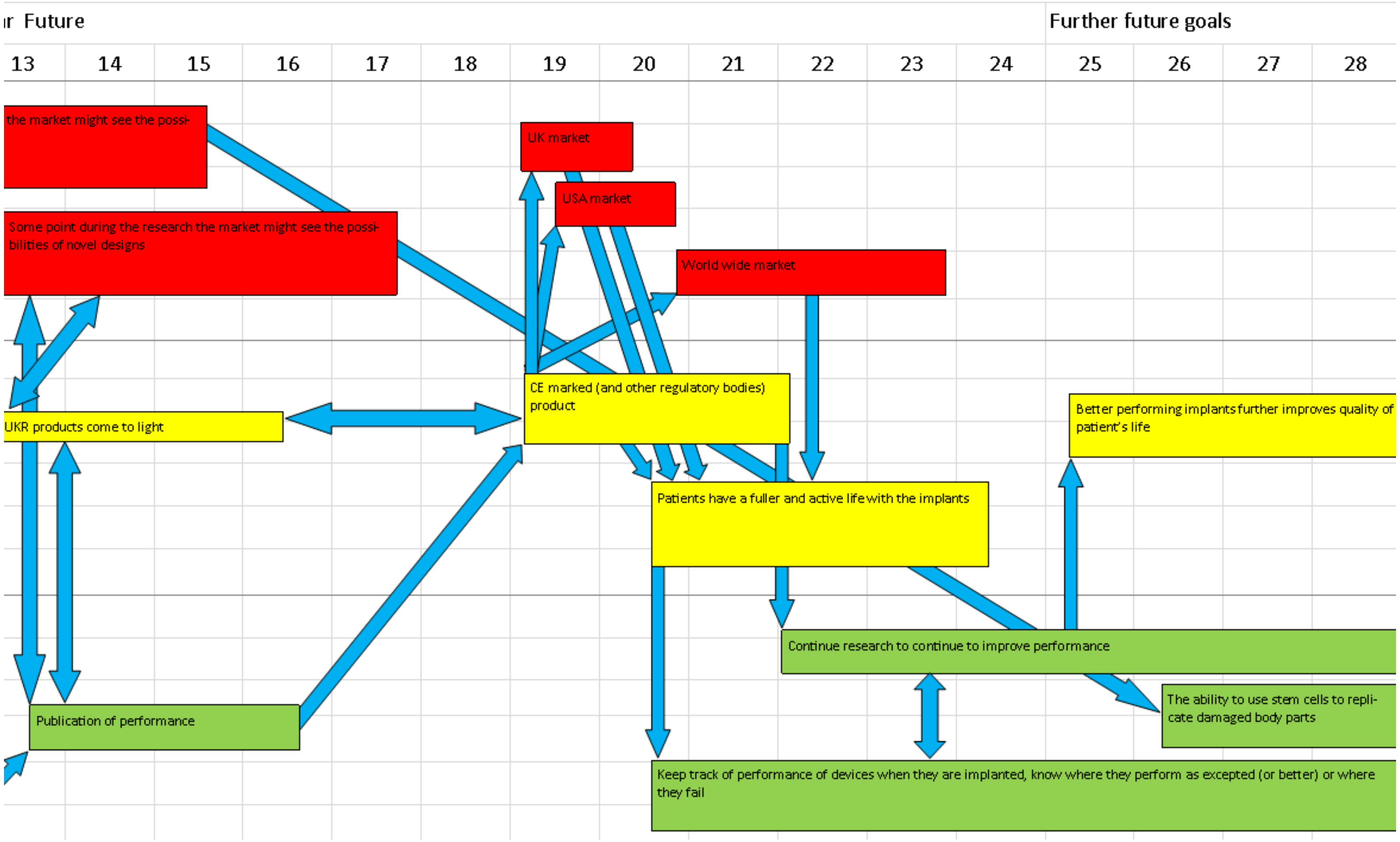
- Zimmer’s NextGen articular surface insertion instrument (TKR) batch was made out of the wrong material specification. It was prone to fracture, thus a possibility of leaving metal particles behind.

Appendix 4: Mind Maps



Appendix 5: Road Map




r Future
Further future goals
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the market might see the possi-
UK market
USA market
Some point during the research the market might see the possibilities of novel designs
World wide market
UKR products come to light
CE marked (and other regulatory bodies) product
Better performing implants further improves quality of patient's life
Patients have a fuller and active life with the implants
Continue research to continue to improve performance
Publication of performance
The ability to use stem cells to replicate damaged body parts
Keep track of performance of devices when they are implanted, know where they perform as excepted (or better) or where they fail

Appendix 6: 32 attributes for Pugh's PDS

Number	Attribute	Was used in PDS?
1	Performance	Yes
2	Environment	
3	Material	Yes
4	Maintenance	Yes
5	Competition	Yes
6	Target Product cost	
7	Patents, Literature and Product Data	The final PDS
8	Legal	The final PDS
9	Safety	The final PDS
10	Standards and Specification	Yes
11	Documentation	
12	Testing	The final PDS
13	Quality and Reliability	
14	Aesthetics, Appearance and Finish	
15	Life in Service	The final PDS
16	Product Life Span	
17	Shelf Life	
18	Time-Scales	The final PDS
19	Customer	Yes
20	Ergonomics	
21	Installation	Yes
22	Company Constraints	
23	Market Constraints	
24	Political and Social Implication	
25	Processes	
26	Manufacturing Facility	
27	Disposal	
28	Shipping	
29	Packing	Yes
30	Quantity	
31	Size	Yes
32	Weight	

Appendix 7: Initial PDS

List Number	Description of Specification
1.01	Overall to have better performance than current UKR
3.01	To be made out of biocompatible material
3.02	To be made out of reliable material
3.03	If possible, have a material that will help healing, anti-rejection, and/or anything else I can think of
4.01	No surgical or invasive maintenance
4.02	If possible, to have non-invasive maintenance to extend the life of the product
5.01	Better and/or cheaper than the competition
10.01	Must fully comply with CE mark (and FDA)
10.01	Must fully comply with Medical Device regulations
19.01	Patient to match requirement to allow them to have UKR
19.02	Hospital staff fully trained
21.01	Needs to be surgeon friendly (see subset of criteria)
21.02	To be integrated with NavioPFS
21.03	Doesn't need other tools (or at least no specific tools) than the NavioPFS
29.01	Packing process needs to sterile
29.02	Packing keeps the product sterile
29.03	Opening the packaging is compatible with operating room procedures
29.04	Clear labelling
31.01	Range of sizes to fit majority of the population
31.02	Small as possible (while keeping the anatomical features it is replacing) so to preserve bone

Appendix 8: TRIZ 40 principles

1. Segmentation
2. Extraction
3. Local Quality
4. Asymmetry
5. Combination
6. Universality
7. Nesting/nested doll
8. Counterweight
9. Prior Counteraction
10. Prior Action
11. Cushion in Advance
12. Equipotentiality
13. Inversion
14. Spheroidal – curvature
15. Dynamicity
16. Partial, overdone or excessive action
17. Moving to a new dimension
18. Mechanical vibration
19. Periodic action
20. Continuity of useful action
21. Skipping/rushing through
22. Convert harm into benefit/blessing in disguise/turn lemons into lemonade
23. Feedback

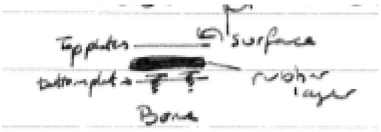
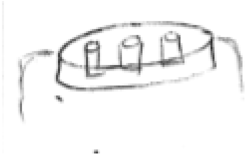
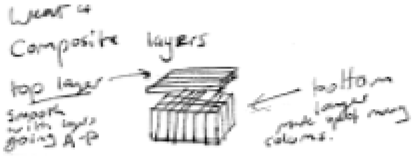
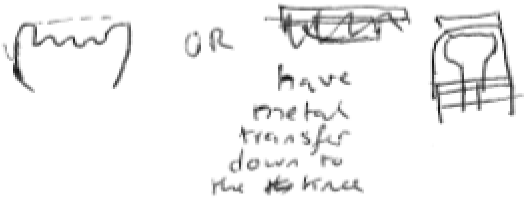
24. Mediator/intermediary
25. Self-service
26. Copying
27. Inexpensive short life
28. Replacement of a mechanical system
29. Use pneumatic or hydraulic systems
30. Flexible film or thin membranes
31. Use of porous materials
32. Changing the colour
33. Homogeneity
34. Rejecting and regenerating parts
35. Transforming physical or chemical states
36. Phase transition
37. Thermal expansion
38. Use strong oxidisers
39. Inert environment
40. Composite materials

Appendix 9: Lists of the Ideas Generated

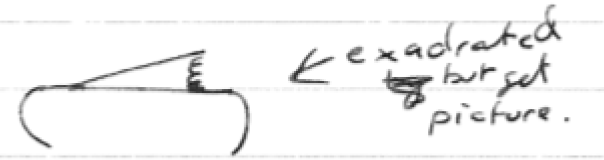
Non-Implant Related Ideas	
Idea	Description and any drawings
1(16)1	Have the burring arm fully tracked that it does not require infrared tracking when burring the tissue.
1(2)2	Have an optical camera for tracking instead of IR and this will remove the tracking jigs. The jigs take up a bit of space and they get in the way while burring. The calibration of the system and patient's knee can be set-up with IR that is then removed for the optical tracking.
1(2)3	The surgeon's attention is split between the monitor and the patient's knee, if the display on the monitor is projected on to the patient's knee then the surgeon has full attention on the burr with all the required information.
2(22)1	Because the surgeon needs to learn new skill to use robotic technology and this may cause a learning curve in surgeries. The system needs to have all stages as instinctual as possible.
2(25)1	Have the system cut and fit the prostheses as this will remove an human error and the surgeons do not require to learn new skill sets.
2(?)1	To have the prosthesis require the same/similar skill sets as other prostheses on the market, this means the surgeons and supporting staff don't require extra training because they can transfer their existing skills.
4(2)3a	Have the system do all of the work. The system will require surgeon to input the patient's knee location etc. and the system will do the rest (this is a bit like idea 2(25)1). If this could be done then it could make the surgeons feel obsolete.
4(2)3b	Have the system do none of the work. The system only does what the surgeon wants it to do and nothing more.
δi	Batman with special glasses
δ1	Remove the knee and batman uses it as a weapon
δ2	Chemicals/enzymes to make the cartilage regrow.
δ5	Surgeon wears x-ray (or visualising) glasses.
γ2	Topical plaster (applied to the skin covering the knee) that helps the knee.
γ3	Plaster that assists with growth by releasing drugs and growth properties.
ζ1	Use bubble wrap or mattress or memory foam.
ηi	Stem cells that increase cartilage growth.

η1	Take (stem) cells from damaged bone and recycle them.
η2	Inject the stems cells on the damaged area.
η3	Super growth formula
λ3	Grow cartilage first to detect if there are any growth problems.
ξ1	Scan the knee in the operation (not CT)
oi	Computer simulation/modelling

Implant Designs but not necessary connected to UKR knee with a NavioPFS system	
Idea	Description and any drawings
2(6)5	Have the prosthesis with a solid lubricant already attached.
2(25)2	Have a material that can re-polish itself after it gets scratched.
4(2)1	Remove the burr and have the prosthesis cut the tissue required.
3(31)2	Make the prosthesis porous to allow the cement to penetrate the surface and have a greater adhesion. An additional would be to have the prosthesis in position before pumping the cement (not necessary PMMA) through the pores of the prosthesis
♫(1)3	To have more components. Have the different features (gliding, shock absorbing, transferring loads etc.) are different parts of the component that are connected.
♫(3)1	Have the material encourage bone growth
♫(3)2	Make the component composite. Have one end properties different from the other end. For example, have the articulating end smooth and glide-able and the end in contact with the bone to be shock absorbing.
♫(♫)1	Reabsorb the wear material. Like the silicon packets for absorbing water, have the wear absorbed and transferred onto the site of wear or have it transfer to the apposing side.
♫(♫)2	Have the material release positive modulators into the synovium fluid that will help to fight/prevent tissue damage from wear (particles).
♫(♫)3	Have a material that replenishes itself in the joint so that when it worn away it is waste that the joint can excrete and can absorb/adsorb material back into the prosthesis.
♫(♫)4	Have a hydrostatic material that response similarly as meniscus and bone.
♫(30)1	Have metal on metal but there is a film over the metals that makes it slide-y
♫(30)2	Have metal on metal and the film covering the metal attracts the protein to line the components. This would provide a small cushions that prevents the film for wearing away and thus the wear particles will be protein based.
5(1)2	Remove the need of two tibial components by just having the whole tibia part out of polyethylene
3(16)2	Have the side next to the bone be porous so that the cement can channel up into and this allows extra space for the cement in areas that obtruding thus could prevent the misaligning or protrusion of the prosthesis caused by cementing.
π_4	Have hammered in pegs that have barbs to prevent pull-out.

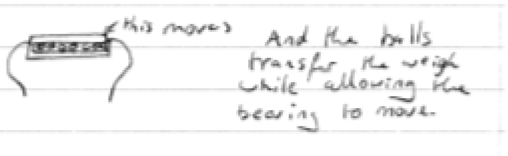
π_8	Suction cup prosthesis; it sticks on to bone (and it draws up tissue into the prosthesis).
π_{12}	Little hooks place on the bone and prosthesis before cementing
σ_4	Base plate secured by screws into bone 
σ_5	As σ_4 but swap out the spring with a rubber layer instead
ρ_3	Glue and strategically placed screws
ρ_8	Super stick padding.
Integrate 1	Spring (or similar) to produce a force on to the bone to increase Wolfs' law and to encourage bone to grow in the prosthesis. 
Integrate 3	Infusion of stem cells or bone grafts into the prosthesis to have an integrated zone (chemotaxis).
Wear 2	{Idea taken from bacteria in building cement.} The prosthesis is self-healing, when the prosthesis fractures or wears it produces replacement material.
Wear 3	Biominic of the fibre arrangement of cartilage.
Wear 4	Simplify wear 3 by having a composite material comprised of two layers; the top layer has the fibres parallel to the surface for smoothness and the second layer the fibres are in columns. 
Transfer 1	Springy material to transfer load to desired points.
Transfer 2	Composite material and have the middle layer a cushion/transfer zone
Transfer 3	The prosthesis material (metal or similar) spanning from the rims of the cortical bone or have the material wrapped down and attached to the outer surface of the bone. 

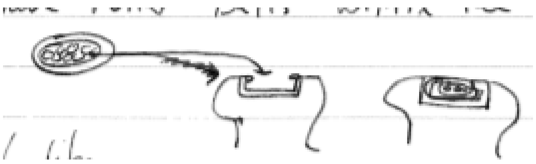
Anchoring 1	Apply additional weight/load to keep the prosthesis in position. Done by ligament tension or screws that tightened over time.
Anchoring 2	Vacuum and suction of the material below to keep the prosthesis in place.
Anchoring 3	Self-tapping screws (once implanted) that with loading will further deepen into the bone.
Kinematics	Mould a prosthesis to the patient through kinematic wear/squishing. This way the patient’s body determines the kinematics of the prosthesis.
Pain	Infuse with pain relief drugs.
γ_i	Stick a plaster on rather than remove the damaged tissue.
γ_1	Sticker to replace the gliding properties of the bone.
ε_i	Use a chewing gum material.
ε_1	Use the gum to stick/mould to the cut-out shape, this produces a smooth surface finish.
ε_2	Use the chewing gum as a shock absorber.
ε_3	Stick the gum on top the surface to act the new surface.
ε_4	Composite gum: one to replace bone and one to replace the meniscus.
ζ_i	Spring or spring like materials
δ_3	Batman (and robin) shaped implants. [would be so cool]
δ_4	Batwings wrap around the bone.
λ_i	The prosthesis contains cartilage that provides a scaffold for the cartilage to grow over (ReGen).
λ_1	Patient specific scaffold so no rejection.
λ_2	Add drug to reduce rejection or reduce inflammation or to stimulate bone/cartilage regrowth.
λ_4	Include a bone scaffold too.
μ_1	Bio-friendly adhesive.
μ_2	Bio-friendly adhesive made from edible glue (sugar base maybe?)
μ_3	Material that will wear but it is replaced with patient’s bone tissue.
μ_4	Make an equation prosthesis made with long term material.
ν_1	Made with durable material.
ν_2	Software or wireless strain gauges to measure if bone damage is still occurring.
ν_3	Have the prosthesis material properties the same as the patient’s bone properties to reduce wear/dismatch.
o_3	Scan the knee at home before the operation as part of the pre-op planning.
o_4	Do a key-hole operation at home with a nurse. (save operation time)

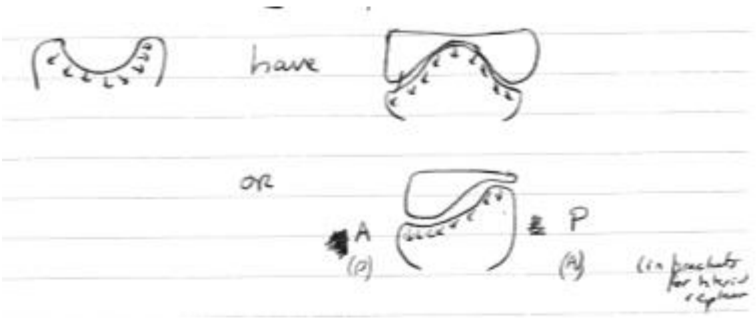
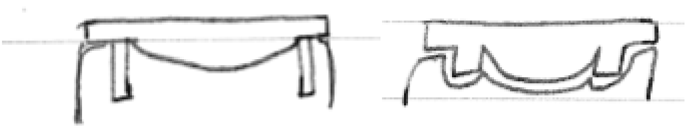
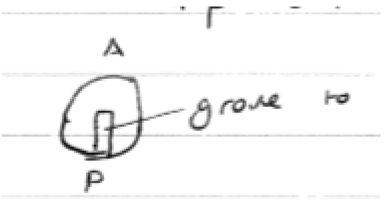
$д_1$	Harvest a small plate of bone during the removal of bone tissue. The harvested plate is placed into the prosthesis to encourage bone growth in both direction through the prosthesis.
$д_2$	Have growth/metabolic components within the prosthesis.
$д_2$	Have a bone cement that penetrates the bone matrix to stimulates growth, over time it is metabolised and replaced with bone tissue.
$г_1$	Have a design that the femur to roll across the tibia surface; i.e. rolls and moves, there is no stationary 'wheel spin'.
$г_3$	Spring load one side to encourage the condyle to move over the tibia and not be stationary. 
$г_6$	The femur component has a ball roller.
$г_4$	The condyle component is shaped so that it rolls without slide or being stationary naturally.
$б_2$	Have a material in the middle of them implant to keep the pressure on the femoral component. 
π_7	Two plates with a screw that self-tightens.
σ_8	Modular two piece tibial component. The base layer screws into place and a smooth top plate snaps fit on to the base plate.
ρ_2	Really strong Velcro on the bone and prosthesis
Wear 1	Injectable material to replenish the worn material 

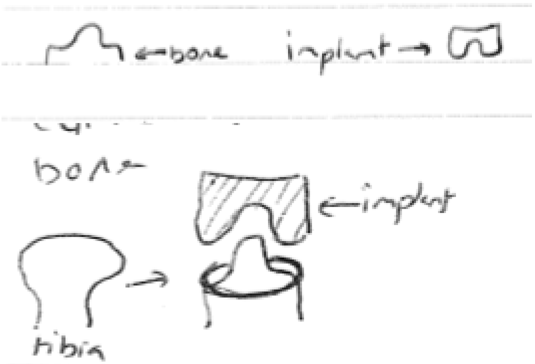
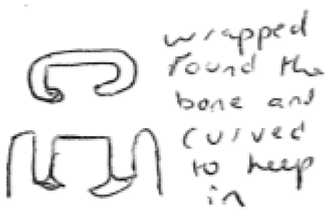
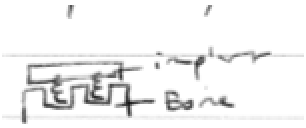
Implant Design for NavioPFS	
Idea	Description and any drawings
2(6)1	Have the implant modular so that the implant can have the same interconnecting parts for a resurface, UKR, Bi-laterial UKR, TKR etc.
2(6)2	The same ideas as 2(6)1 but instead of modular have it so that the implants between the range are pretty much the same.
2(¿)1 (find middle number)	Have a the prosthesis and procedure as complicated as possible in order to increase the surgeon’s attention and concentration.
2(6)3	Make the prosthesis cementless because having a cemented prosthesis requires extra skills, the bone cement properties vary with the mixing procedure, and potentially removing the cement can increase versality.
2(6)4	Have the prosthesis be its own glue, this can be done by: Have the underside a soft and malleable material to mould into the burred surface for a snug fit. Have the underside pre-glued like an envelope.
2(6)6	Have the prosthesis already in place before adding the cement through channels in the prosthesis. This certify the prosthesis will be in the planned position at the right height. The cement can also be less viscous as it doesn’t require to be putty like. The bone underneath could also have grooves to help with the flow of cement.
2(20)1	Have an injectable prosthesis. In theatre the prosthesis is created on the patient’s knee and then a cap can be placed on top for solid lubrication.
2(19)1	When burring the bone is removed a bit at a time for each part of the implant.
4(2)2	Not to remove all the tissue, only the necessary tissue. This prevents a bulk removal of tissue and the surgeon is more likely to follow the system.
4(2)4	Eliminate the need for pre-made and trial prostheses. The prosthesis is position on the prepared tissue and the burr curs the prosthesis into shape and polishes the surfaces.
4(31)1	Before the surgeon cements the prosthesis to the knee, a substance is “poured” into the bone matrix to have a foundation a little like reinforced substance.
3(1)1	Have the tibial components in parts, so modular idea.
3(1)2	Only treat the tibial components as if they were in parts.

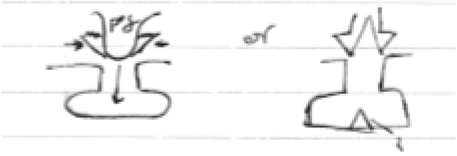
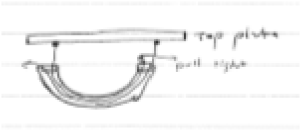
3(1)3	Spilt the tibial component in several features according to the design, for examples these could be the different features: the removal of unhealthy tissue as part of the prosthesis, the attachment features, and cementing features. Each feature is done one at a time in order so it splits up the process. The prosthesis can also be separated by the features and only remove unhealthy bone.
3(2)1	Only remove unhealthy bone. Are there common areas that get damaged?
3(2)2	Remove need for bone cement.
3(4)1	It is hard to remove all the tissue at the knee posterior. Have it so not all the plateau needs to be removed. There will be some parts of the cortical rim at the back, front, and sides; this allows reduction of tissue removal as well as difficult to reach areas.
3(4)2	Like 3(4)1 but have a change in depth from posterior to anterior and/or medial to lateral etc.
3(4)3	Have a unique prosthesis shape that reduces the removal of tissue but provides good stiffness, transfer of load (no stress concentration or shielding), cement channels for adhesion etc. it also solves the problem for the surgeons not fully complying with the system.
3(14)1	Have an inlay that is curved so it does remove excess healthy tissue, this can only be done with a burr. The curve can apply forces like arch.
3(14)2	Have the curve direct the forces to areas that are designed for loading rather have forces going through area that might break, or fracture.
3(14)3	Use curves to allow healing around the prosthesis while reduce the bulk removal of tissue
3(16)1	The removal of all tissue isn't required, have the prosthesis adapt to (purposed) incomplete action of the surgeon.
3(16)3	Don't have the whole area and depth removed; have it so that the surgeon can burr away at the bone will they think they are at a healthy bone foundation. The prosthesis adapts to the depth of bone removal. This means they are removing as much bone that is needed.
3(31)1	Like above (3(16)3), the surgeon removes the unhealthy bone and exposes the spongy bone. In the prosthesis has two parts, first applied is the liquid or liquid like base layer that strengthens the weakened bone and is the foundation for the solid (metal) part of the prosthesis. Like resurfacing with reinforcement.
5(1)1	Have the design of the prosthesis not to involve complicated angles of attack (i.e. pegs) and only need the surgeon to access from one direction.
5(7)1	Have a thin film to hold together a gel/putty material that is the prosthesis
5(7)2	Have a telescopic prosthesis, one size fits all. Maybe include a gel/putty/powder to fill the gaps, especially at full extension.

5(2)1 [♫(2)2]	Remove deep drill hole and straight edges.
5(2)2	Only remove unwanted tissue and nothing extra (unless it gives easier access for the surgeon).
5(37)1	Have a compacted material that expands to fill the space.
♫(1)1	Replace deep drilled holes with channels or patterns
♫(1)2	To have the implant modular
♫(4)2	The prosthesis has a curved or arched or slanted bottom to transfer the load.
♫(4)3	The prosthesis' shape on the articulating surface is designed to help load transfer for walking and running etc.
♫(6)1	Have the prosthesis be a bag of 'putty', this will act like a shock absorber, a lubricant/smooth surface, and force distributer
♫(6)2	The idea from ♫(6)1 with a metal cap on top to prevent the putty from moving.
♫(8)1	The tibial component is a spring like material that is covered by a metal plate. When there is no pressure from the femoral component the tibial component is prominent and in contact with the femoral component. When there is pressure the tibial component retracts and moves to allow a good load transfer.
♫(10)1	Opposite to a modular system. Have yjr prosthesis have everything and it is easy to break away unneeded/extra material – a cut to size sort of thing.
♫(15)1	The meniscus bearing is mobile and the fixation of the bearing is within the bone.
♫(15)2	The meniscus bear is attached to the elastic anchor in the bone (or prosthesis).
♫(15)3	There is a spring material under the articulating surface of the tibial component that will help the sliding of the condyle.  but have it so: allowing the condyle to slide forward
♫(15)4	The middle part of the prosthesis are roller balls so there isn't any gliding of material.  And the balls transfer the weigh while allowing the bearing to move.

♫(15)5	Have the roller balls within the meniscus bearing and the material goes all the way round like a conveyer belt. 
♫(♫)5	Early intervention to replace the meniscus or cartledge by adding a sticker or similar.
♫(18)1	Add vibration within the tibial plate that, this will help the condyle move forward and stick less to the bearing as it moves.
2(?)2	Have the prosthesis complex so to increase the surgeon's attention and compliance with the system (but not too complex that they then won't want to use the prosthesis)
♫(4)1	To remove in a forward (or side) fashion that the burr can help enter
α_i	Use dental putty or another mouldable substance
α_1	The dental putty is used to mould into the knee and it harden with a shiny (smooth) surface.
β_i	Scan the knee to make specific and 3D printed prosthesis.
β_1	CT scan and print before the operation.
β_2	Scan and print in the operation room.
β_3	3D print cells onto a cartilage scaffold.
β_4	3D print onto the knee.
θ_i	Make the prosthesis curvy
θ_1	[picture]
θ_2	Add chewing gum to prevent further damage. Plus a protective coating for the implant
ι_i	Hexagonal of different depths to fit into damaged areas
ι_1	Use computer modelling to make hexo-panels (as pre-op modelling/planning)
ι_2	Hexagonals that are bio-degradable (to an extent) so they mould into place.
ι_3	Hexagonals that are bio-degrade to allow bone regrowth through the gaps and hexagonals.
ι_4	Sink into the bone
ι_5	Have grooves that join the hexagonals together
ι_6	Have grooves/teeth to place into the boney bed
ι_7	Have a central hexagonal that has an umbrella like cap where other haxagonals fit underneath with different depths.
κ	Have a ski path along the knee.
μ_i	Curvy implant and keep the meniscus. (minimise waste)

ν_i	3D print that is patient specific, images are taken from CT or x-rays.
ξ_i	3D scan bone to get the shape of the knee and then 3D print of the scan to grow the artificial bone.
o_1	Have software the models the individual knee and picks out damaged area for 3D printing that is specific.
o_2	3D injection onto the patient's knee
б$_1$	Different shapes of the bone and prosthesis interface: 
б$_3$	The prosthesis is curved so to distributes forces. 
г$_2$	Have a groove for the prosthesis to slide along. 
г$_5$	Have a conveyor belt system to the surface is always moving with the femoral component and thus does not wear.
π_1	Have channels and groves on the back of the prosthesis that matches with the bone grooves.
π_2	The prosthesis has a dovetail groove for fixation

π_3	The prosthesis fits on top of a boney mound. 
π_5	The bone has undercuts for a prosthesis with stiff rubber or memory alloy to slot into. 
π_6	Inflatable prosthesis.
π_9	Angles pegs for fixation. 
π_{10}	Stepped prosthesis. 
π_{11}	The prosthesis wraps around for fixation. 
π_{13}	Spring within the bone. 
σ_1	1D/2D corrugation.
σ_2	Toroidal/annular corrugation.

σ_3	Rectangular in and out pegs.
σ_6	Have a snap-fit like pegs that hold the prosthesis in place by undercuts. 
σ_7	Mini pegs and hooks on prosthesis and bone, they slide into place. 
σ_9	Fluid filled prosthesis, it fills up cavities created with the burr. 
σ_{10}	The burr creates a two-ended burrow into the bone. Wire is feed through the burrow and tied to the prosthesis. 
σ_{11}	The fixation of the prosthesis to the bone is like a bayonet fitting (spring loaded)
σ_{12}	The bone and prosthesis fits together like IKEA fittings
σ_{13}	Memory alloy changes to desired shape on implantation, this fixes the prosthesis in place.
π_{14}	The prosthesis has a slight slope down to the cut wall and it is rounded. This is to prevent stress shielding.
ρ_1	Snap fits in place
ρ_4	Cut tiny holes, seal them, fit the implant and create a vacuum.
ρ_5	Cut screw thread on the bone and thread the prosthesis.
ρ_6	Lock and key fitting. The prosthesis can only fit in one way.
ρ_7	3D Jigsaw puzzle. The prosthesis is built on in layers and only fits in one way.
ρ_9	Cut a turn and lock pattern onto the bone.
ρ_{10}	‘Male’ and ‘female’ attachments.
ρ_{11}	Expanding adhesive foam.
ρ_{12}	Prosthesis comes as two locking pieces that can only fit in one way.

ρ_{13}	Compressive loading used in constructions (i.e. bridges) to allow movement but transfer loads.
ρ_{14}	Rectangular pegs with hooks for attachment of the prosthesis.
Integrate 2	Reverse pegs and maybe have the undercuts.
Cement 1	Compromise/partial cementing. Either have the cement just to hold the prosthesis in position to help with osseointegration or use the cement like grouting.
Cement 2	The cement is applied using a designed injector that applies the cement in the correct place with the right volume.
Modular based	This is to have a prosthesis that can interlock to increase in size, this allows the surgeon to only remove unhealthy tissue and leave healthy tissue rest untouched.
Mosaic	This is to remove unhealthy bone and cartilage to be replaced with sections to be inserted into the holes as anchors to hold an interlocking mosaic like cover over the tibial plateau.

Appendix 10: 6-3-5 Tables and Instructions

A blank example of a 6-3-5 table:

Name	Idea 1	Idea 2	Idea 3
A			
B			
C			
D			
E			

Instructions to both groups:

The ideas were asked to be how to fully utilise the robotic orthopaedic tools with Unicondylar/Unicompartmental) Knee Replacement/Arthroplasty prostheses (the participants have previously been briefed regrading this technology and procedure).

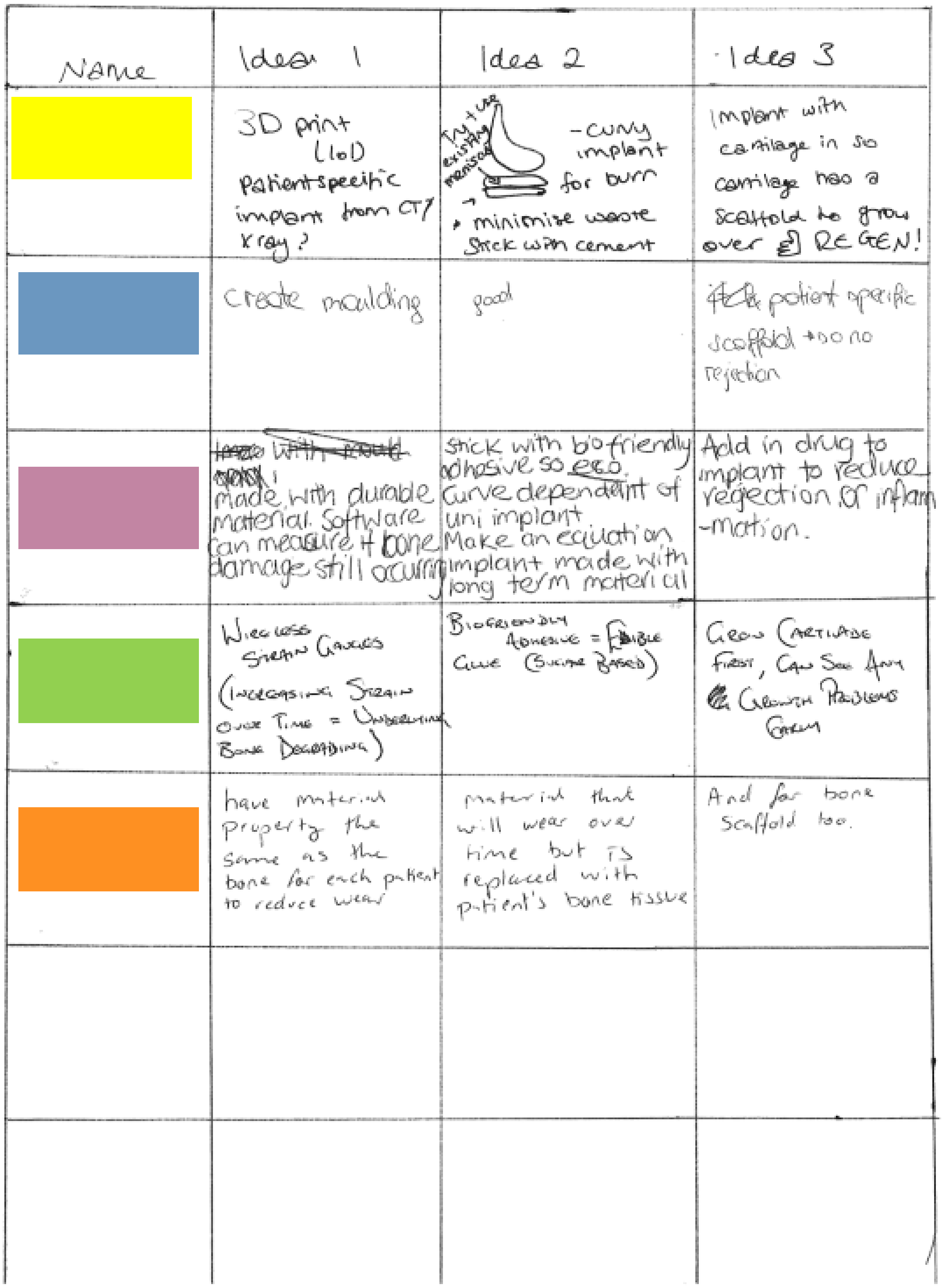
In the blank table on the paper in front of you please enter your name on the first box under name. When the timer is started you will have 5 minutes to write down or draw ideas up three in total. When the timer goes off, please pass the paper to your left; the person on your right should be handing their paper with their 3 ideas on the top row. *Fill in the sentence below with the respective group*. The papers are passed and the timer is reset for the same number as participants, so at the end of exercise the participant will have their original paper with their name on the top row.

The instruction to the fresh group

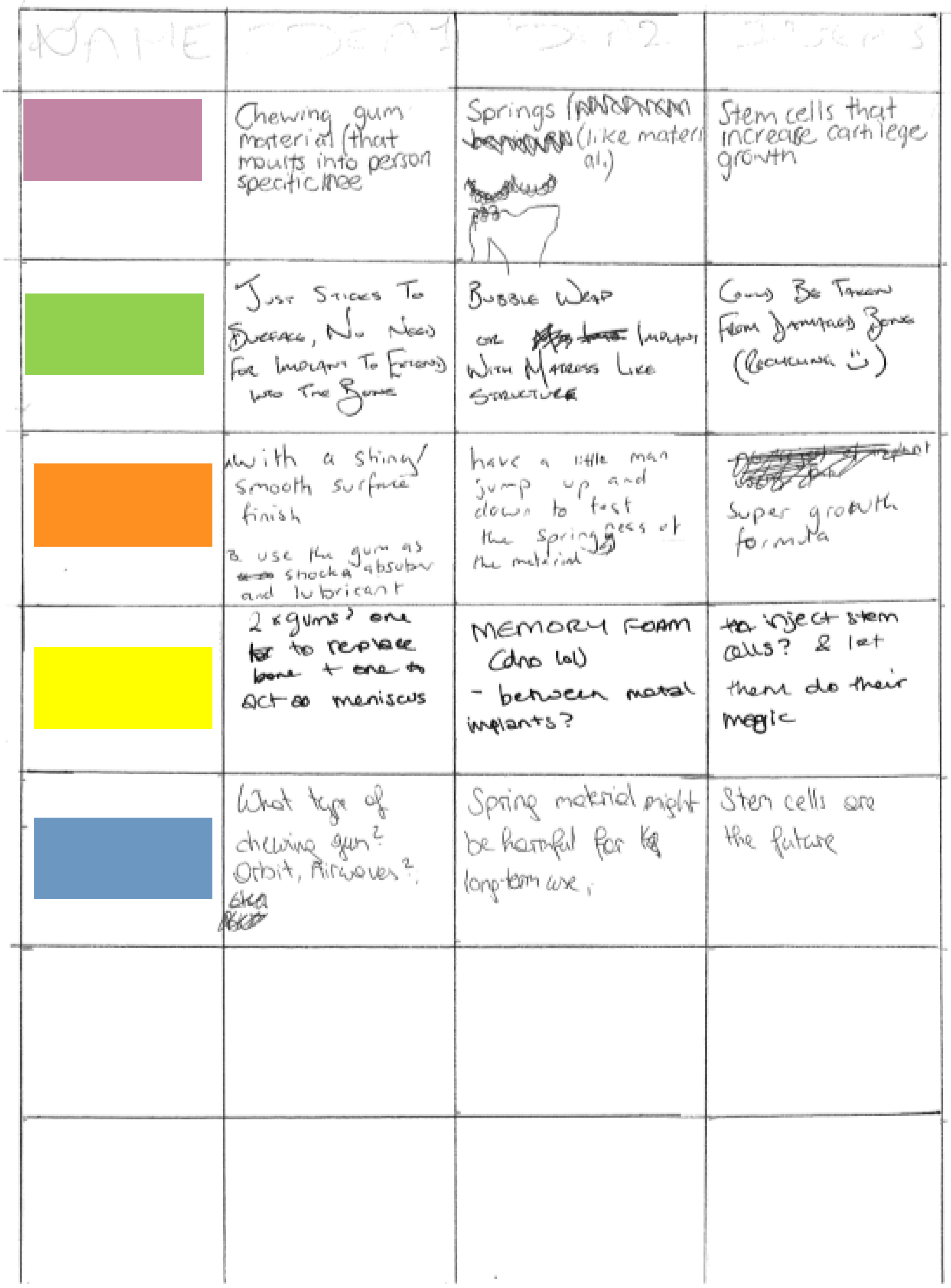
The timer is reset to allow 5 minutes to read the previous ideas to influence the further develop up to 3 more ideas based on the them.

The instruction to the Skilled group

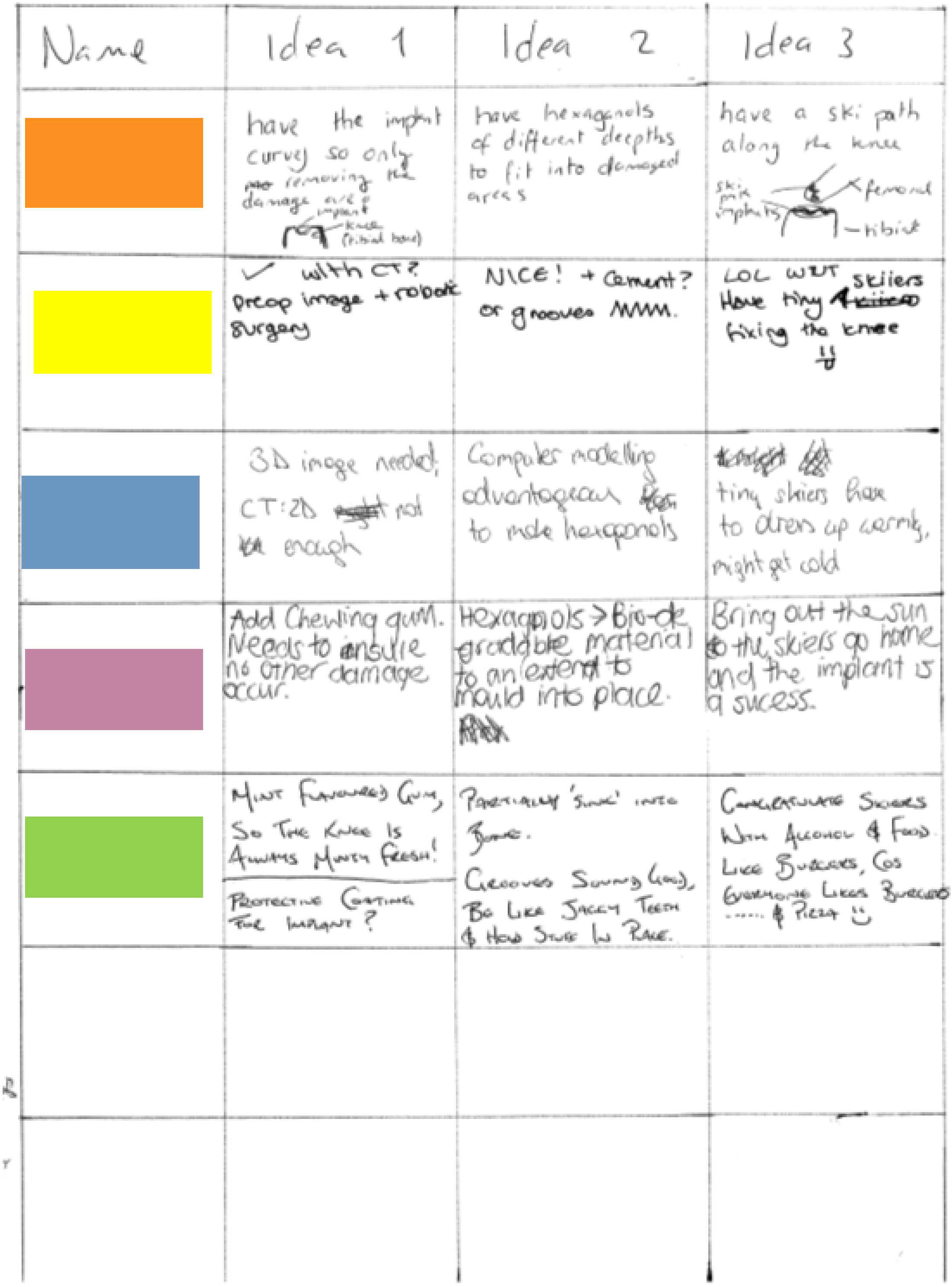
The timer is reset to allow 5 minutes to read the previous ideas as inspiration to help develop more ideas or enhance current ideas; again, the maximum number of ideas is 3 in the 5 minutes.



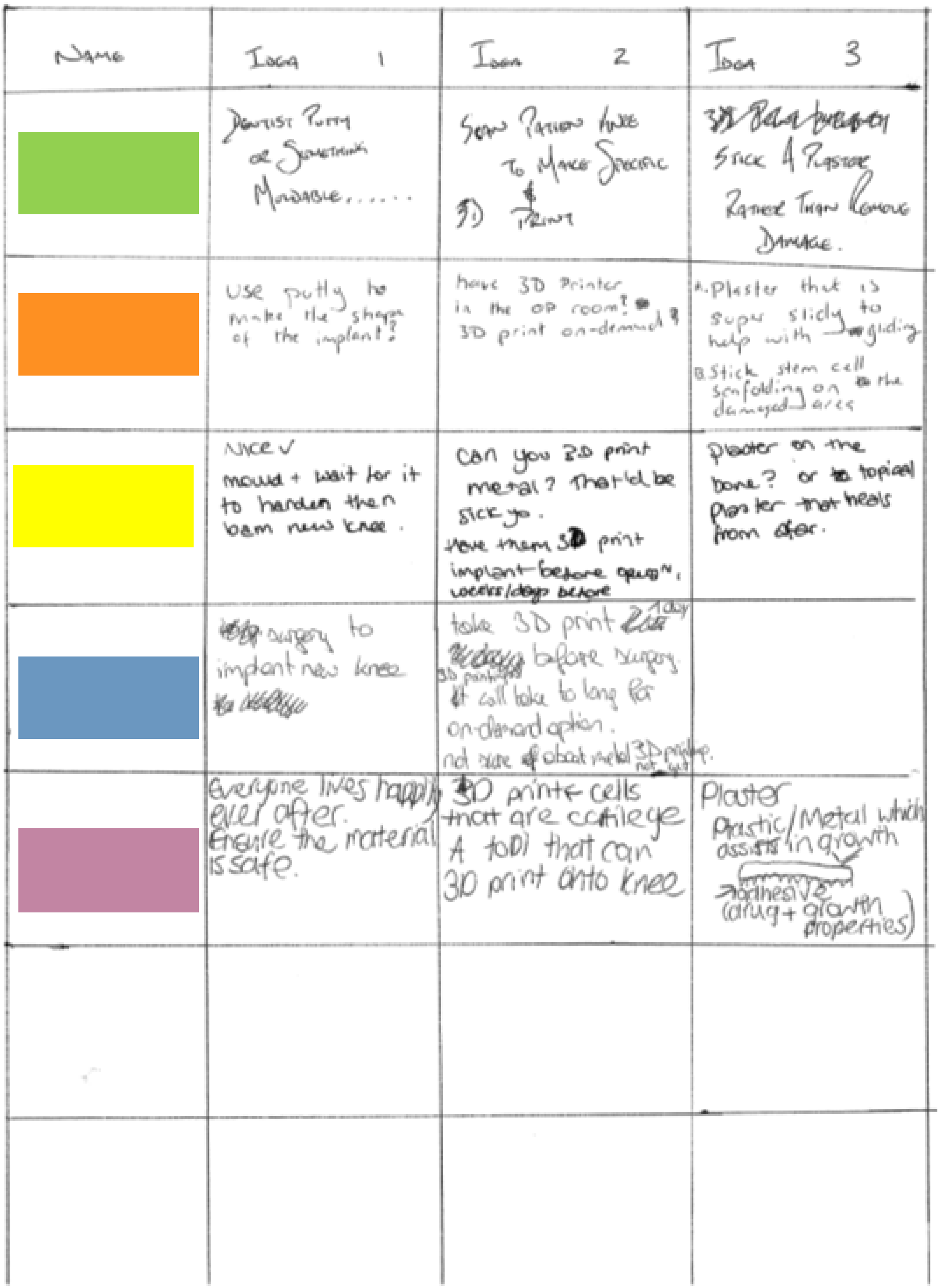
Name	Idea 1	Idea 2	Idea 3
🟨	3D print (IoD) Patientspecific implant from CT/ Xray?	Try + use existing menisci -curvy implant for burr → • minimise waste Stick with cement	implant with cartilage in so cartilage has a scaffold to grow over REGEN!
🟦	create moulding	good	~~[illegible]~~ patient specific scaffold + so no rejection
🟪	~~[illegible] with mould~~ ~~[illegible]~~! made with durable material. Software can measure if bone damage still occurring	stick with bio-friendly adhesive so eco. curve dependent of uni implant Make an equation implant made with long term material	Add in drug to implant to reduce regection or inflam-mation.
🟩	Wireless Strain Gauges (Increasing Strain over Time = Underlying Bone Degrading)	Biofriendly Adhesive = Edible Glue (Sugar Based)	Grow Cartilage First, Can See Any ~~[illegible]~~ Growth Problems Early
🟧	have material property the same as the bone for each patient to reduce wear	material that will wear over time but is replaced with patient's bone tissue	And for bone scaffold too.



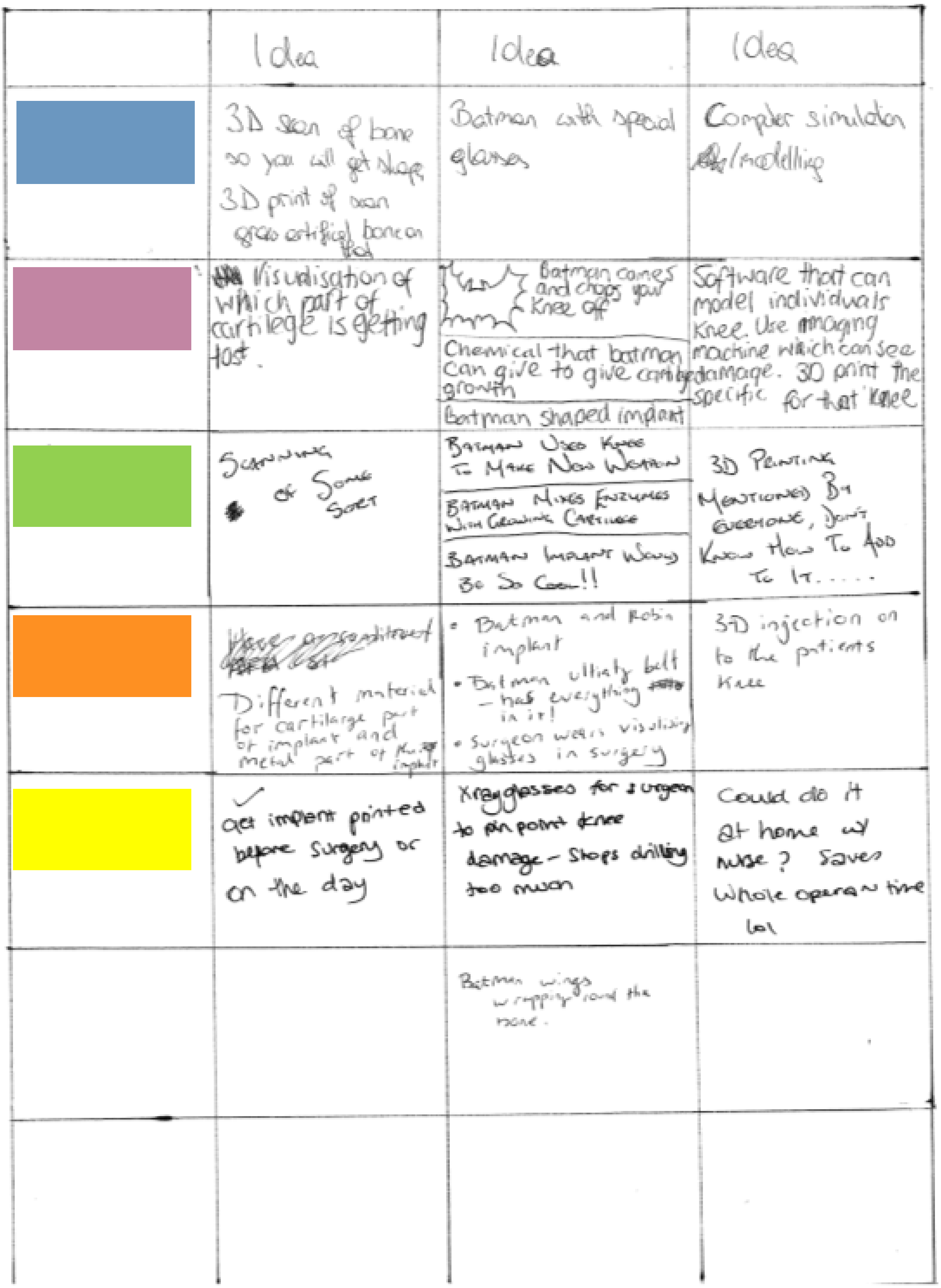
NAME	IDEA 1	IDEA 2	IDEA 3
🟪	Chewing gum material (that moulds into person specific knee	Springs (like material)	Stem cells that increase cartilege growth
🟩	Just Sticks To Surface, No Need For Implant To Extend Into The Bone	Bubble Wrap or Implant With Matress Like Structure	Could Be Taken From Damaged Bone (Recycling ☺)
🟧	with a shiny/ smooth surface finish 2. use the gum as shock absorber and lubricant	have a little man jump up and down to test the springiness of the material	Super growth formula
🟨	2 x gums? one ~~for~~ to replace bone + one to act as meniscus	MEMORY FOAM (dno lol) - between metal implants?	~~to~~ inject stem cells? & let them do their magic
🟦	What type of chewing gum? Orbit, Airwaves?	Spring material might be harmful for long-term use.	Stem cells are the future



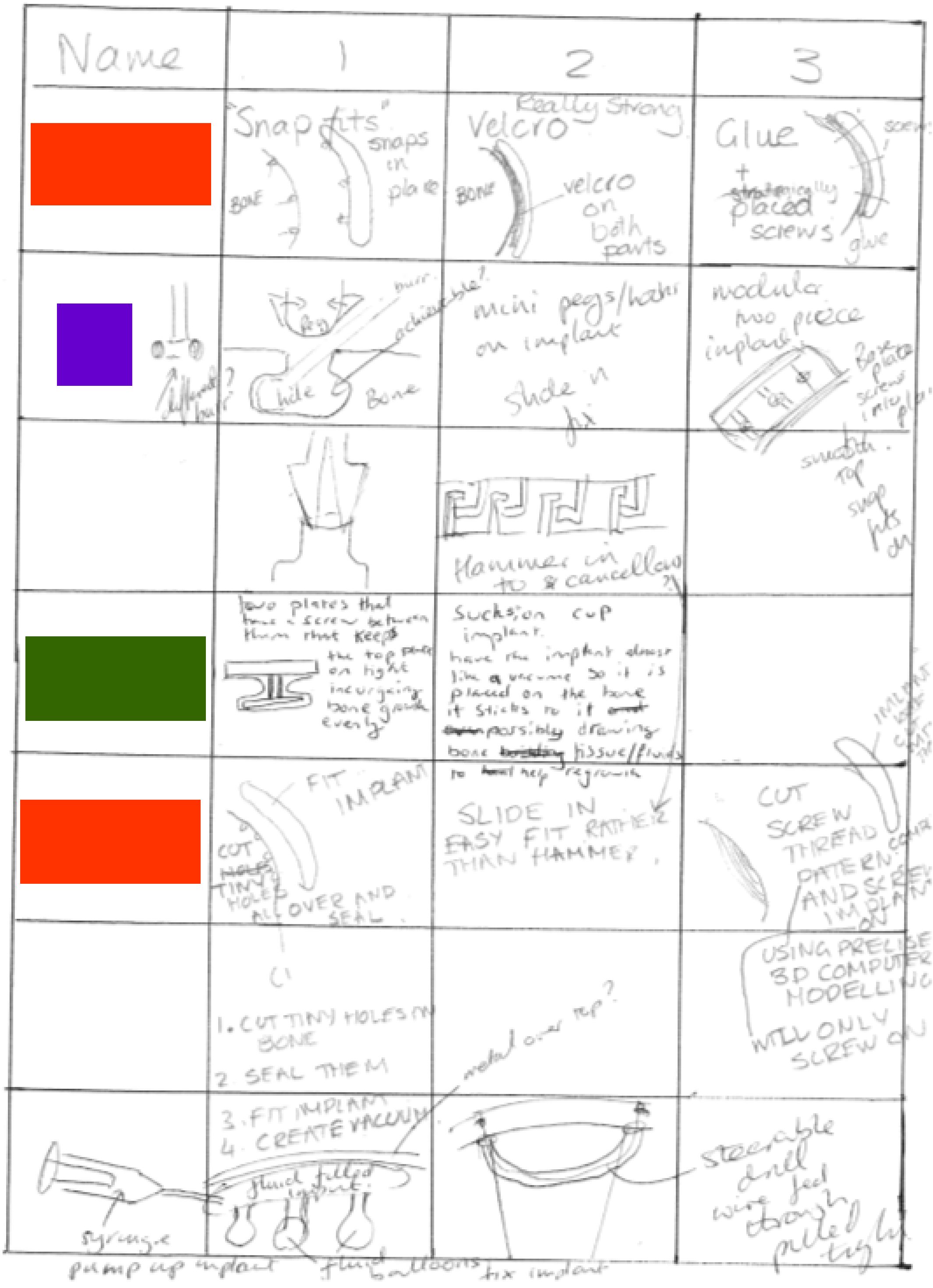
Name	Idea 1	Idea 2	Idea 3
[redacted]	have the implnt curve so only ~~no~~ removing the damage area implant knee (tibial bone)	have hexagonals of different deepths to fit into damaged areas	have a ski path along the knee ski path implants femoral tibial
[redacted]	✓ with CT? Preop image + robotic surgery	NICE! + Cement? or grooves MMM.	LOL WUT skiers Have tiny ~~[illegible]~~ fixing the knee ☺
[redacted]	3D image needed; CT: 2D ~~might~~ not ~~[illegible]~~ enough	Computer modelling advantageous ~~[illegible]~~ to make hexagonals	~~[illegible]~~ tiny skiers have to dress up warmly, might get cold
[redacted]	Add Chewing gum. Needs to ensure no other damage occur.	Hexagonals > Bio-degradable material to an extent to mould into place.	Bring out the sun so the skiers go home and the implant is a sucess.
[redacted]	Mint Flavoured Gum, So The Knee Is Always Minty Fresh! Protective Coating For Implant?	Partially 'Sunk' into Bone. Grooves Sound Good, Be Like Jaggy Teeth & Hold Stuff In Place.	Congratulate Skiers With Alcohol & Food Like Burgers, Cos Everyone Likes Burgers ...... & Pizza ☺



Name	Idea 1	Idea 2	Idea 3
[redacted]	Dentist Putty or Something Mouldable.....	Scan Patient Knee To Make Specific 3D Print	~~3D Bone breaker~~ Stick A Plaster Rather Than Remove Damage.
[redacted]	Use putty to make the shape of the implant?	have 3D Printer in the OP room? 3D print on-demand?	A. Plaster that is super sticky to help with ~~[illegible]~~ gliding B. Stick stem cell scaffolding on to the damaged area
[redacted]	Nice ✓ mould + wait for it to harden then bam new knee.	can you 3D print metal? That'd be sick yo. Have them 3D print implant before operation, weeks/days before	plaster on the bone? or ~~to~~ topical plaster that heals from after.
[redacted]	~~[illegible]~~ surgery to implant new knee ~~[illegible]~~	take 3D print ~~2~~ 1 day ~~[illegible]~~ before surgery. 3D printing it will take to long for on-demand option. not sure about metal 3D printing. not yet	
[redacted]	Everyone lives happily ever after. Ensure the material is safe.	3D printe cells that are cartilege A tool that can 3D print onto knee	Plaster Plastic/Metal which assists in growth → adhesive (drug + growth properties)

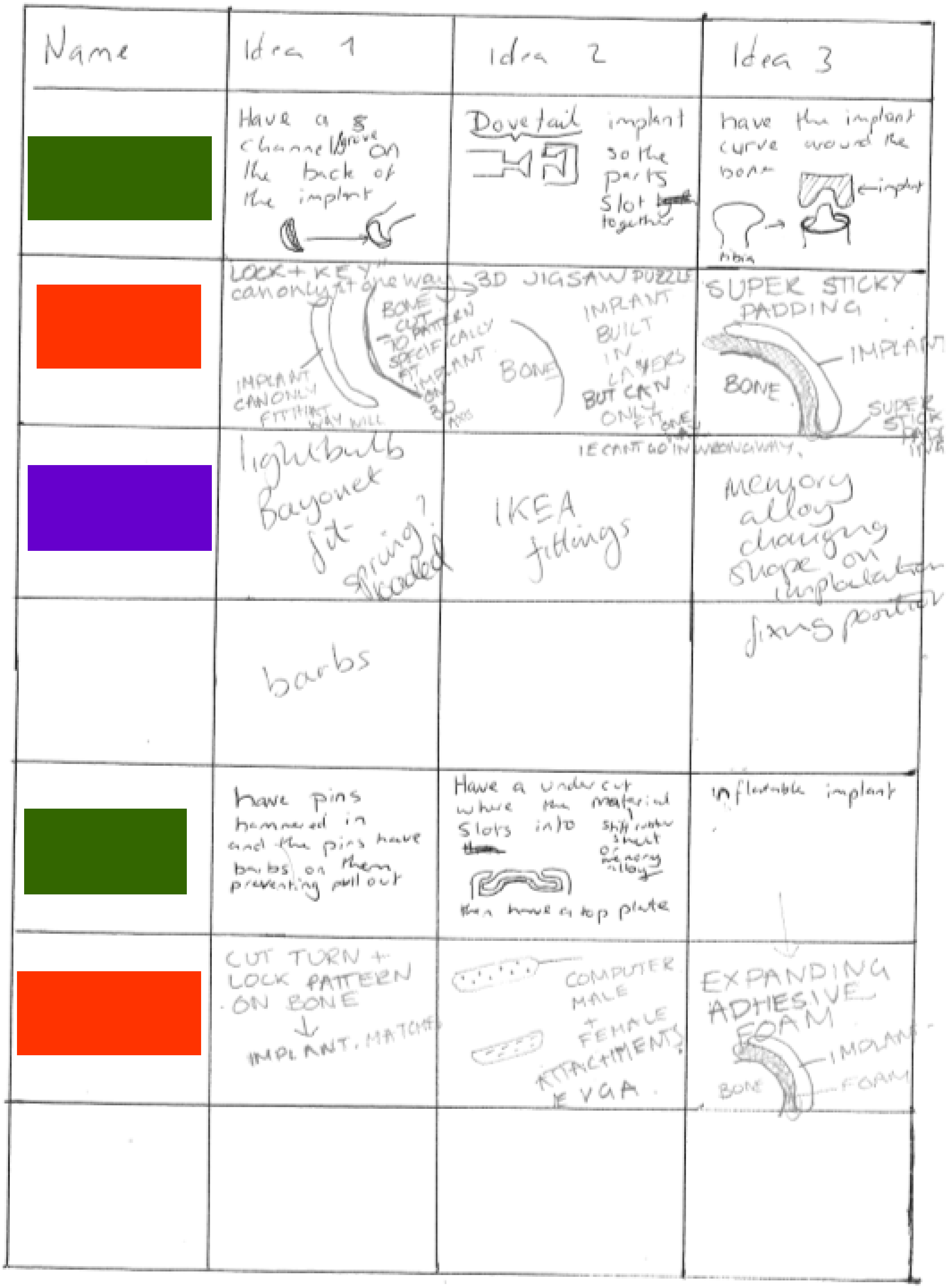


	Idea	Idea	Idea
🟦	3D scan of bone so you will get shape 3D print of scan grow artificial bone on that	Batman with special glasses	Computer simulation /modelling
🟪	Visualisation of which part of cartilege is getting lost.	Batman comes and chops your knee off Chemical that batman can give to give cartilage growth Batman shaped implant	Software that can model individuals knee. Use imaging machine which can see damage. 3D print the specific for that knee
🟩	Scanning of some sort	Batman uses knee to make new weapon Batman mixes enzymes with growing cartilage Batman implant would be so cool!!	3D printing mentioned by everyone, don't know how to add to it....
🟧	Different material for cartilarge part of implant and metal part of knee implant	• Batman and Robin implant • Batman ultility belt – has everything in it! • Surgeon wears visualising glasses in surgery	3D injection on to the patients knee
🟨	✓ get implant printed before surgery or on the day	Xray glasses for surgeon to pin point knee damage – stops drilling too much	Could do it at home w/ nurse? Saves whole operation time lol
		Batman wings wrapping round the bone.	

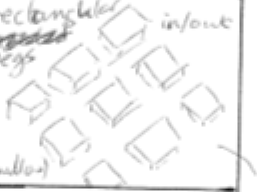
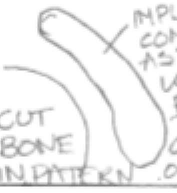
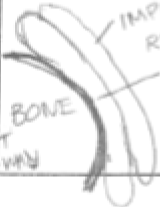
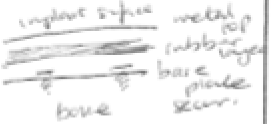


Name	1	2	3
[redacted]	"Snap fits" snaps in place BONE	Velcro Really Strong BONE velcro on both parts	Glue + ~~strategically~~ placed screws glue
[redacted] different burr?	peg burr. achievable? hole Bone	mini pegs/holes on implant slide n fix	modular two piece implant Base plate screws into plate
		Hammer in to cancellous	smooth. top snap fits on
[redacted]	two plates that have a screw between them that keeps the top piece on tight incurging bone growth evenly	Suction cup implant. have the implant almost like a vacume so it is placed on the bone it sticks to it ~~and~~ ~~[illegible]~~ possibly drawing bone ~~[illegible]~~ tissue/fluids to ~~heal~~ help regrowth	
[redacted]	FIT IMPLANT CUT ~~HOLES~~ TINY HOLES ALL OVER AND SEAL	SLIDE IN EASY FIT RATHER THAN HAMMER.	CUT SCREW THREAD PATTERN AND SCREW IMPLANT ON
	1. CUTTING TINY HOLES IN BONE 2. SEAL THEM	metal over top?	USING PRECISE 3D COMPUTER MODELLING WILL ONLY SCREW ON
syringe	3. FIT IMPLANT 4. CREATE VACUUM fluid filled implant		steerable drill wire fed through pulled tight

pump up implant fluid balloons fix implant



Name	Idea 1	Idea 2	Idea 3
[redacted]	Have a ~~s~~ channel/groove on the back of the implant	Dovetail implant so the parts slot ~~together~~ together	have the implant curve around the bone implant tibia
[redacted]	LOCK + KEY "can only fit one way" BONE CUT TO PATTERN SPECIFICALLY FIT IMPLANT ON 3D AXIS IMPLANT CAN ONLY FIT THAT WAY WILL	3D JIGSAW PUZZLE BONE IMPLANT BUILT IN LAYERS BUT CAN ONLY FIT ONE IE CAN'T GO IN WRONG WAY.	SUPER STICKY PADDING BONE IMPLANT SUPER STICKY PADDING
[redacted]	lightbulb Bayonet fit spring loaded?	IKEA fittings	memory alloy changing shape on implantation fixing position
	barbs		
[redacted]	have pins hammered in and the pins have barbs on them preventing pull out	Have a undercut where the material slots into ~~them~~ stiff rubber sheet of memory alloy then have a top plate	inflatable implant
[redacted]	CUT TURN + LOCK PATTERN ON BONE ↓ IMPLANT. MATCHES	COMPUTER MALE + FEMALE ATTACHMENTS EG VGA.	EXPANDING ADHESIVE FOAM IMPLANT BONE FOAM

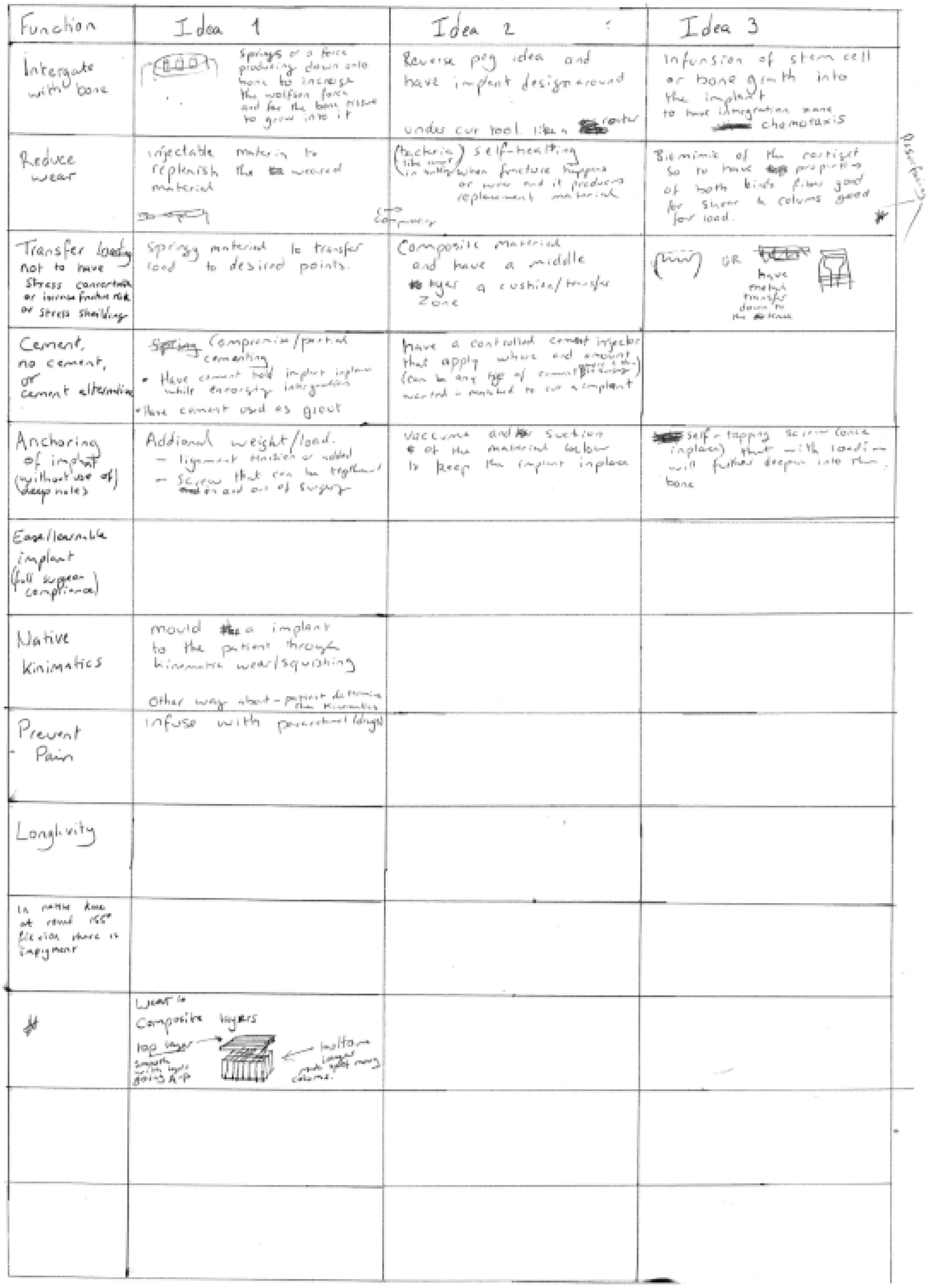
Name	1	2	3
[redacted]	corrugation 1D/2D 	toroidal/annular corrugation 	rectangular ~~[illegible]~~ pegs in/out  (shallow)
[redacted]	Angled pegs to transfer load  tibia	Have a stepped implant to allow implant snug fit and equal transfer of load 	 wrapped round the bone and curved to keep in
[redacted]	 IMPLANT COMES AS TWO LOCKING PIECES THAT CAN ONLY FIT ONE WAY CUT BONE IN PATTERN	 IMPLANT RUBBER FLEXIBLE COMPRESSIVE LOADING USED IN CONSTRUCTION I.E. BRIDGES TO ALLOW MOVEMENT BUT TRANSFER LOAD BONE	RECTANGULAR & PEGS WITH HOOK FOR ATTACHMEN OF IMPLAN 
[redacted]		 implant surface metal top rubber layer base plate secur. bone	 top [illegible] base plate
[redacted]	little hooks that are placed before cement on bone and implant  cement implant hooks bone	Spring within the bone  implant bone	

Appendix 11: Technical Aspects Table

A blank example of a 6-3-5 table.

Function	Idea 1	Idea 2	Idea 3
Function 1			
Function 2			
Function 3			
Function 4			
Function 5			

The following table was obtained from the exercised with skilled members.



Function	Idea 1	Idea 2	Idea 3
Intergate with bone	Springs or a force producing down onto bone to increase the wolfson force and for the bone tissue to grow into it	Reverse peg idea and have implant design around under cut tool like a router	Infunsion of stem cell or bone groth into the implant to have integration zone chemotaxis
Reduce wear	injectable materia to replenish the weared material	(bacteria like ones in butter) self-healing when fracture happens or wear and it produces replacement material Composite	Biomimic of the cortiset so to have properties of both kinds fibre good for shear & colums good for load. #
Transfer loading not to have stress concentration or increase fracture risk or stress shielding	Springy material to transfer load to desired points.	Composite material and have a middle layer a cushion/transfer zone	OR have metal transfer down to the [illegible]
Cement, no cement, or cement alternative	~~Spring~~ Compromise/partial cementing • Have cement hold implant inplace while encouraging integration • Have cement used as grout	have a controlled cement injector that apply where and amount (can be any type of cement/bio-glue) needed = matched to cur a implant	
Anchoring of implant (without use of deep holes)	Addional weight/load. – ligament tension or added – Screw that can be tightened in and out of surgery	vaccume and suction of the material below to keep the implant inplace	self-tapping screw (once inplace) that with loading will further deepen into the bone
Ease/learnable implant (full surgeon compliance)			
Native kinimatics	mould a implant to the patient through kinematic wear/squishing Other way about - patient determine the Kinematics		
Prevent Pain	infuse with paracetamol (drugs)		
Longlivity			
In native knee at round 155° flexion there is impingment			
#	Wear is Composite layers top layer smooth with layers going A-P bottom layer made up of many columns.		

Osteoporosis

Appendix 12: PMI

PMI Table for the Group of Non-Implant Related Ideas

Idea ID	Positives	Minus	Interesting	Possible to implement?	Possible for the implant?
1(16)1	Very accurate and precise can do any implant size and shape	Would take up a lot of space Remove the need of the surgeon Expensive won't be keyhole or minimal incision	Fully robotic orthopaedic tool		
1(2)2	It moves away from clumpyness and free up space	Not very practical and reduces accuracy	Reducing the system's "footprint"		
1(2)3	Only needs to look at one place	Adds more components and set-up to the system	A small reduction of the system's footprint but mostly helps the surgeon carry out the operation	Very possible, have multiple camera to reduce the inference	Nope - system
2(22)1	Leaning and skill learning	Time, money, effort, and compliance			
2(25)1	Removes human error and more complicated shapes can be made reproduced	Who takes responsibility? And what do the surgeons do now?		Has been done	
2(?)1			see 2(22)1		

4(2)3	Prevents the surgeon from doing half the work if it makes them do it all or does it all for them		Have the surgeon to do all the input, designing and planning	Possible	Possible but really is a system thing
δ_i	Batman can do everything	Does not exist	The glass idea, something like google glasses	Possible	Nope - system
δ_2	Has the bone and cartilage self heal and in theory that is better overall	How to apply the chemicals and enzymes to stay put and do the job and not create growth clusters	Self healing	Possible	More possible if integrated with implant
δ_5	Removes monitor and maybe even the IR cameras that will reduce system footprint and increase the surgeon's concentration	Money, accuracy and practicality	Google glasses	Possible	Nope - system
All η	No rejection, self healing	How to apply the stem cells to stay put and do the job and not create growth clusters	Utilise the natural power of re-growth.	Possible	More possible if integrated with implant
κ	Utilises the system's potential of any shapes	Not a clear idea			Idea that curves can be implemented
All ζ; ε_2	Prevents sudden and damaging loading to be transferred between surfaces and may even provide support and transfer of loading	What would this material be and does it exist?	Composite material	Possible	Yes

O_1	Patient specific theory is it should restore native kinematics that provide a better performing and lasting implant. Plus should ideally only remove the needed tissue.	Requires a 3D printer that has a material that can be utilised in operation (though could be used to be a mould but that would require pre-op scanning).	3-D idea is good for patient specific	Possible	Make the implant 3D printed could be a future investigation
O_2	3D print into the knee should do the above plus can do better anchoring and integrating than the above.	Does the material exist? How would the system do it?	No faffing, straight into the patient... Boom! Done to the exact shape and position wanted	Possible	It’s more a system thing but it is possible to have an injectable implant
O_3	The patient doesn't need to go visit hospital or GP. Allows the surgeon to do pre-op planning	CT scans are radiation - is that necessary? Could other scanning techniques (like ultra sound) produce accurate representation of the knee. Also how transportable are these options and can the health professionals go around visiting?	Pre-op planning and patient feels there is a little more control over the whole op	Possible	Nope - system
O_4	Reduces scars, damage to healthy tissue and healing time.	Awkwardness and accuracy of performing through a small hole. Implant also needs to be adapted for entering the patient though the small hole	Small is key	Possible	More a system thing but the implant needs to implanted via small gap. So requires new system and implant

Cement 2	Only the right volume of cement is used in the right area. Implant will have full and effect coverage of cement without having too much to sit proud of the cut surface	More parts to the system and can the cement be injected in such a manor?	Controlling all aspects of the operation	Possible	A system thing but implants can be design/evolve round this new addition

PMI Table for the Group of Implant Related but not NavioPFS Ideas					
Idea ID	Positives	Minus	Interesting	Test it	further investigation
2(6)5	Reduces the number of components and possible failures	A greater number if different size implants,	Composite material	No	
2(25)2	Reduces friction and helps the surfaces glide ->potentially reduce wear	Self-polishing - does that mean extra wear particles?	A material/design that "self heals"	Not this idea	
4(2)1	Only the right shape and volume of bone is removed and reduces the number of parts to the system	Practicality	Have the implant (or implant imitator) to remove material	Not this idea	
3(16)2	The cement penetrated the implant creating a stronger bond between the surfaces	Finding a suitable material	How far does cement penetrate the bone? And how far would it penetrate a porous material	Can possibly test the idea but not much else	See what my cements hold and see if it is worthwhile looking into it
3(31)2	Same as above, but I guess it is more a greater surface and pockets to generate adhesion	Material, can a rough material do the same?	Link to cement test		
5(1)2	Reduces the number of components	-	-	Possibly	

P(1)3	Each part has it own roles	More parts	More specific to the person, or an integrated implant		Further thought needed
P(3)1	Self-healing and/or bone integration into the implant for better anchorage	Can all bone qualities do that? Can it be done and how long will it take?		Possibly but will involve live tissue, and then there is time frame	
P(3)2	Takes away different part and make the implant into one component. Could be close to the native tissue(s)	Material existence			Would be nice to see further into this idea and relating ideas
P(P)1	Wear particles don't leave the joint and enter cells (locally or systemically)	Can it work?		Not really	
P(P)2	Instead or along with wear particles these modulators do positive affects in the joint	Can it work?	Have material that excretes similar substances as the native tissue?	Not really	
P(P)3	Like P(P)1 as particles don't leave the joint and in this case the wearing material in theory won't get smaller	Can it work? Will the particles go to the area needing to have material reabsorbed or go to area that doesn’t need the extra material		Not really	

P(P)4	This should replicate the function the lost tissue used to do. Proved some shock absorbance.	Is that necessary, one reason is to exchange nutrients and waste.	Use what is already there to produce implant that can replicate what has gone	More thought needed	
P(30)1	Removed the plastic insert and ideally has no wear particles produced	Does such a non-wear film exist? Shock absorbing and load transfer	Look into the need for a shock absorber and load transfer	Thought and investigation into the interesting column	yes
P(30)2	The wear particles produced is non-harmful already present in the joint	Will it reduce wear and friction?	Sacrificial replenish-able material	Possible	
All γ; ε_3	Keeps the knee intact and	Damaged bone is left and may never heal and affect healthy bone	Like a resurfacing	No	Maybe further thought
All λ, ξ	Self healing into the implant that can provide anchoring and load transference		Self-healing	Not in my project	But definitely look into
δ_1	Takes out all patient specific and difficulties with soft tissue and ligaments	Knee is very complicated that presently can't be replaced			
δ_3	Provide better anchoring without			Not really	

	having to remove extra bone				
$\iota_{2,3}$, $\mu_{1,2,3}$, $\nu_{2,3}$	Self -healing but with the a structure proved that gives way to the native tissue	Where does the scaffolding go?	Can the scaffolding be made out of bone and cartilage minerals?	Not really out width the scoop of the project and time scale and the lab experience	
π_4	Only able to go one way and when the bone grows more around it then the anchorage gets stronger	Partly uses brute force which can damage healthy tissue		Live subject may not be feasible	Worth looking into
π_8	None-damaging anchoring	How is the suction maintained?	Using tissue/hydrostatic mechanics		Could be a worth a look but not very promising
π_{12}	Increases surface area and other anchoring properties	More faff than just a rough surface	Methods to increase surface area and anchoring properties	Could	
σ_4 & σ_5	The implant is built on top of the base plate, could be more useful for patient specific and kinematics	The base it to screw into place, is building up stable. Doesn't focus on the attachment as such	Could work on that principle, a base plate/inlay	Possible	Investigate further and idea generation, not all ideas testable
ρ_3	What we have now and it seems to be a good gold standard, can they be better placed and sizes?	Not much different or radical from what there is already in the market			

ρ_8	?				
$г_1$	Takes advantage of reducing wear aspects of rotation bodies	Can it be implemented? Will it match/compatible with natural gait		Nope	
$г_2$	Takes advantage of reducing wear aspects of rotation bodies	Will it be practical or will it cause more wear? Will it transfer load "well"?		Nope	
$г_3$	Suppose to help with wear and encourages movement of the condyle. Could transfer loading to desired areas	Will it work the way it works theoretically? Will the spring wear out?		Could do CAD models	
$д_1$	Goes back up to row 22 but uses what would have been lost in surgery and the implant isn't being replaced just more embedded	Blood/fluid supply to the tissue in the implant		Outwidth the project but could be possible	
$д_2$	Going back to other similar ideas mentioned above				
$д_3$	Cement that rather produces a barrier to implant and bone but as something that provides anchorage for	Finding such a material and/or chemical		Not with this project	

	primary stability and bone growth over time				
Integrate 1	It takes in the bone re-growth factor and works with it use it to make the bone stronger and possibly integrating into the implant	Producing such a force? will it pop out? If the extra force is coming from the condyle will that produce greater wear?	Can this work on cement, cementless and partially cemented implants? Produce the extra force by transforming any shear and torsional into axial?	Some aspects can be tested, like partial cementing with downwards force and brainstorming transformation of force types but really this is further investigation	
Integrate 3	Self healing into the implant that can provide anchoring and load transference		Self-healing and an implant that encourages and works with it	Living tissue	
Wear 2	Self healing from the implant, if the implant starts to fail it will prevent failing farther.	Will it work with implant material and will it pass protocols?	Material and implant that adapts to the patient, wear and fatigue	No	Into self-modifying implants
Wear 3	Uses the natural occurring fibre compilation that both reduces wear and great for transferring load	Able to produce a material	Using what is there to put together an implant design	No	Look into

Wear 4	Takes on board biomedical of wear 3 but in a simple practical manor	Will it the simplistic work	Simplify to the basic principles	Possible	
Transfer 1	Transfer loading where it is desired		Use this idea in conjunction when an implant concept is produced	Possible	Used together with another idea
Transfer 2	Have spread loading, possible also constantly providing force into the tissue	Work?		Possible	
Transfer 3					
Anchoring 1	Can increase the bone growth	How will work could affect the kinematics of the patient and/or require further-up op to fix/remove parts of the implants	There may be a way to harness unwanted forces and have the implant apply extra force to encourage growth	No	Look into harnessing forces
Anchoring 2	No cement, no wear on implant and bone, greater integration of the tissue	Practicality	In combination with other anchoring to increase integration	No	
Anchoring 3	Will constantly make the bone get stronger over time without any medical intervention after the op	Practicality, and will the force become	Can older/damaged/diseased bone still respond to as well to the Wolff's law that will allow bone integration into implants and get denser	No	But a worthwhile investigation for the orthopaedic implant industry

Kinematics 1	Means the implant is adapted to the patient's kinematics and thus natural kinematics	Practicality	Patient determining the shape of the implant	No	
Pain 1	Rescues pain and thus keeps the patient active that could increase the bone density and thus more integrated implant	Pain is a good indicator if something is wrong and blocking some process might not be all good	Infusing the implant with positive chemical	No	

PMI Table for the Group of NavioPFS Implant Related Ideas					
Idea ID	Positives	Minus	Interesting	Test it	Further investigation
2(6)1	Patient and condition specific meaning that it is adjustable and only removes the unhealthy tissue	Failure rate could increase	Modular		Brainstorm how to do this
2(6)2	As above		More thought into it		
2(?)1	No short cuts and could bring in many different positive influences	Being too complicated			
2(6)4	Removes the need of using cement and other anchoring techniques	Exist	How can this be done? Very putty and sticky that it moulds and sticks into shape	No	
2(6)3	Listed pg 71	No primary stability, will bone become dense and integrate			
2(6)6	Stops the cement making the implant prominent	Air pockets, penetration	Using the PFS feature of the BBT to inject cement where needed	No	Can it be done with/without BBT and is it worthwhile
2(20)1	Every knee is unique to the patient and surgeon.	Finding the right material and will it have everything a implant needs	It uses an extended possibility of the PFS and is 100% patient specific. It is pretty much like 3D printing	No	

2(19)1	The implant doesn't necessary need to change, it makes the cutting job into stages rather doing it all at once	Will more stages "trick" the surgeon to not take shortcuts	Segment the process	Theoretical not much else	
4(2)2	Only removes damaged tissue	More an idea than implant design	Take forth the idea	No	
4(2)4	Standard implant that is modified in surgery depending on the removal off damaged tissue	Tracking the implant, modifying the implant cleanly and effectively	In surgery modification	No	
3(1)1	Covered before				
3(1)2	Reduces the chances of the surgeon taking shortcuts and make the surgeon think a little more in surgery, it also reduce tissue removal if the implant and cutting takes section by section	Doesn’t address implant, this design needs to be thought. It also extra software programming	Are some parts of the more likely to be damaged than other and thus need more tissue removed? Is there area that would benefit from a deeper/shallower tissue removal	Theoretical	
3(1)3	Reduces the shortcuts the surgeon may want to take. If the patient doesn't need certain aspects then it doesn't need to be added. Each feature will have a single role that could reduce failure	More parts more failure points, the surgeon might not like the complicatedness and may not use the system	Modular	Theoretical	

3(2)3			A bit like 4(2)2 and its is more like an idea/goal		
3(2)2	Removes any problems associated with bone cement	Stability and bone's ability to regrow/remodel	More an idea than a design	Living tissue models of bone regrowth and cement damage - so no	
3(4)1	This allow an easier surgery and for surgeons to fully follow procedure and less shortcuts and this will do	Will it affect the performance of the implant	More an idea than a design at the moment		
3(4)2	More thought out to the above				
3(4)3	If there is too much/little or wrong shapes then there might not be optimal stress transfer and thus increase failure rate	This might be different for different people's kinematics and the disease/pathology	More an idea than a design at the moment		
3(14)1	Reasons listed on pg 88				
3(14)2	So loading is being applied to the right area of the bone that would allow the greatest bone re-modelling and direct away from bone that might be able to adapt or weak that will fracture	Directing the forces	It is an idea rather than a design	Not at the moment	

3(14)3	Self healing and utilises the full functionality of the system and reduces shortcuts	More than idea		Possibly but it is living tissue	
3(16)1	This means the surgeon doesn't need to do all the tiring boring little things from - shortcuts welcomed	Does it define the point of the accurate guidance	Smart implant		
3(16)3	This means the surgeon adapts to the patient's condition and the proved the best possible care and removal of unhealthy tissue while maintaining healthy tissue	Will the implant be adaptable to all the conditions and shapes left behind	Condition controls the software	No	
3(31)1				Possible	
5(1)1	Gives the surgeon easy access to the cutting surface and less likely to do shortcuts	Similar to ones before	Making cuts easier for the surgeon	Theoretical	
5(7)1					
5(7)2	All implants the same and the implant is still modifiable to the patients	The practically and chances of failure	Taking forth the modular implant idea and making all implants the same but still modifiable	No	
5(2)1			More an idea that started the project	Yes	

5(2)2	Just like the others			Yes	
5(37)1	Just like filling foam, it will fit all size cuts	Will it still have the same properties of other implant material or will it fall	Uses the idea like above (5(2)2) to reduce cut size and maintain as much healthy tissue	Maybe if I can find a material	
P(1)1	Channels and patterns will help with cement or other means			Yes	
P(1)2			Idea		more thought
P(4)2	Done this			Possible	
P(4)3	Great for kinematics			No	
P(6)1	Transfer load and prevent high peak loads	Will it work? Will it migrate or leak/leach	Does it need to be putty?	Possible	
P(6)2	Reduce migration/leaking problems and provide a stable surface for the condyles		Putty as a shock and space filler for all cuts. Maybe have a space material that has similar properties as bone	Possible	
P(8)1	Like the above so the shock is absorbed and allows constant pressure on the condyles (great for Wolff's law)	Getting the pressure just right, and be beneficial or cause pain or something		Possible	
P(10)1	Similar to other one above but possibly a little more cleaner	Less adjustable	Implanted adjustable to the cut and patient	No	

P(15)1	Utilising and recycling waste to self heal into the wound	But if bone was being drilled away it is destroyed but also if it usable then what are the chances that the bad tissue will do what you wanted it to do		No	
P(15)2	Again, the same as above	Again, the same as above		No	
P(15)3	Produce positive movement of the condyle and then transfer load well across the implant to the bone	Will it work? Will it more likely to fail?		CAD	
P(15)4					
P(15)5					
P(P)5	Keep the bone and most of all the kinematics and natural tissue	Only work with some conditions what if the damage is into the bone then it is likely to successful		Possible	
P(18)1	Keeps everything moving, no single point of wear.	Beneficial? Failure? Change of battery?		No	
All α; All ε; θ_2	As listed above		Space-filler and doesn’t necessary need to putty like	possible	
All β; ν_i; All ξ	Means implants can be printed in advance with surgery all planned out all	Material be 3D printed, also BBT aren't into pre-scanning		No	

	shapes and sizes can be made produced				
All θ, κ, μ_i	As mentioned above			Possible	
All ι	All fits together, and the shape will match the shape of the removed tissue.	Failure of the parts		Possible, maybe CAD	
δ_4	Can't think of the positives	Will it work into the bone	The initial idea is weird but it has potential maybe?		
o_2	Like this idea, had it before see above			No really	
π_1	Had before			Yes	
π_2	Not coming out	Needs to be side in ooor snap fitted		Yes	
π_3	It works in dentistry	Will it work here? Ligament attachment		Possible	
π_5	It creates better attachment	Pulls or fractures the bone and getting the implant into the void		Possible	
π_6	Like above and a little like the putty and the undercut would be a situation would be solved	Will it state inflated, and could it pop?		Maybe	
π_7	Keeps and generates tension	Could it fracture the bone		Possible, CAD	
π_9	No pull out or stress shielding	Getting them into the bone		Yes	

π_{10}	Transfer load	Angles and edges being concentration points. Will it sit too deep into the tibia/condyle?	Can achieve the same sort of load transfer with a curve like implant	Yes	
π_{11}					
π_{13}					
σ_1	Like some of the above			Yes	
σ_2	Like above			Yes	
σ_3	Like above			Yes	
σ_6	Snap fit that will provide primary stability	Can the bone handle the "pushing" force		Possible	
σ_7	A solution to primary fixation	If the implant is slid in place will it slide back out? How to under cut so many hooks and would it be possible on a macro scale and not the micro scale?	Add in a snap fix idea to the peg hooks	No	
σ_8	Screws don't necessary need to have pre-drill and solves primary fixation that can be adjusted to patient needs that then have a smooth finishing top	Are screws the best rout? Adding in extra components.	If there is a composite material implant this could be a way to go, everything working and a finish on top. Would the layers of different composite material work and avoid stress loading	The composite material and component part	
σ_9	Covered this elsewhere				

σ_{10}	Pull the top plate down and theoretically in place	How beneficial is this extra added loading , will it cause stress points and needless bone removal? Adapting the NavioPFS system		No	
σ_{11}	Like the hook idea that provides primary stability that is likely to slide back out. Also c an be easily taken out and replaced	Getting the undercut and not creating stress concentrations	Springs (like material) to keep in place.		
σ_{14}	Side pins into the ridge possible to reduce shielding		Using curves, grooves	Do cad models	
σ_{13}	The implant can be shaped for implantation which means awkward shapes can be achieved	There might need to be pre-op planning to have the implant the right size, what Stops the implant from remoulding	Like a space-filler but in a metal like form.		
ρ_1	Covered	Would it create pressure point that when loaded could cause fracture			
ρ_2		How to stick the Velcro onto the bone		No	
ρ_4	No bone cement and primary stabilisation plus encourages secondary	How long will the suction last, will it move	"Pull" in tissue to increase integration		

ρ_5	This could be good to transfer the load down into the bone	Could it create stress concentration, and would it to be effective mean a large removal of bone tissue. Also won't it turn/twist when it is place and be off position		No	
ρ_6	Helps with positioning and fixation of the implant		Can be implemented to most design ideas		
ρ_7	It means that all parts fit together and				
ρ_9	Covered similar ideas				
ρ_{10}	Covered similar ideas				
ρ_{11}	Covered similar ideas				
ρ_{12}	Covered similar ideas				
ρ_{13}					
ρ_{14}					
$б_1$	Like one of the suggested above. Can be good for load transfer and provide surgeon with easy access	The slant might allow migration	How the load will transfer and encourages positive movements	Possible	
$б_2$	A similar idea above			Possible	

б$_3$	Could provide a possible good load transfer and protect the edges from fracturing	Could be a little complicated and produces stress concentrating edges. Will it all fit in the tibial plateau		Possible	
г$_4$	No/reduced wear	Is it possible	Idea that isn't necessary associated with BBT	Maybe	
г$_5$	No-reduced wear	Complicated and could increase wear on the bone	A design that isn't going to wear		
Integrate 2	Less tissue to be removed and no deep pin hole to be created	Will the reverse peg be strong enough and will it easier than the pin hole	Reversing the ideas	Maybe	
Wear 2	A bit like both inflatable implant and the 3D implant. It might be a bit more particle and it would take up all the space like the space fillers	Puncture? Migration? Leaching? Material existence	Space filling ideas	Most likely not	
Cement 1	Provides primary stability but can be done for encouraging bone integration	Faffing for not much	Reducing the problem of the cementing negative and provides some of the positive of the cementless implants	Possible, might need living tissue	

Appendix 13: Extra graphs from chapter 8

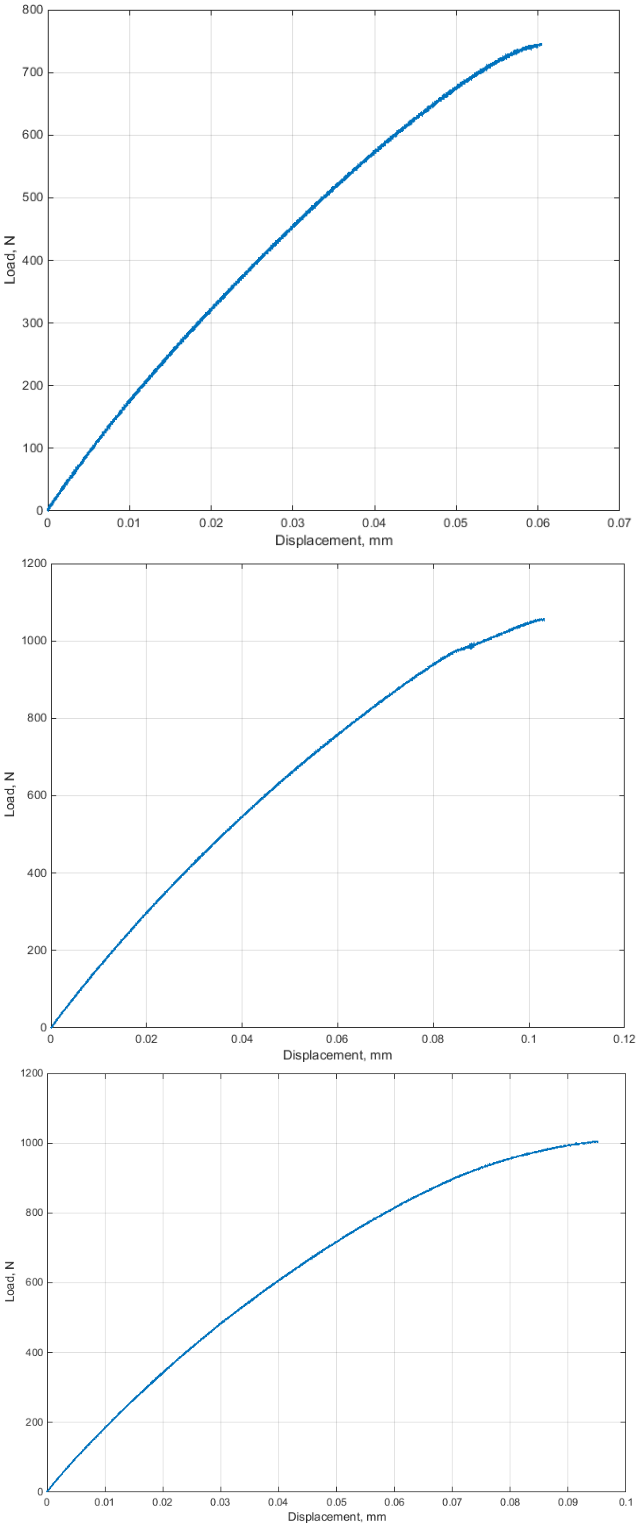


Figure A13.1 Load over Displacement from Example Sample from each Group
Top Graph is the smooth group, the middle graph is the rough group, and the bottom graph that is the mixed group.

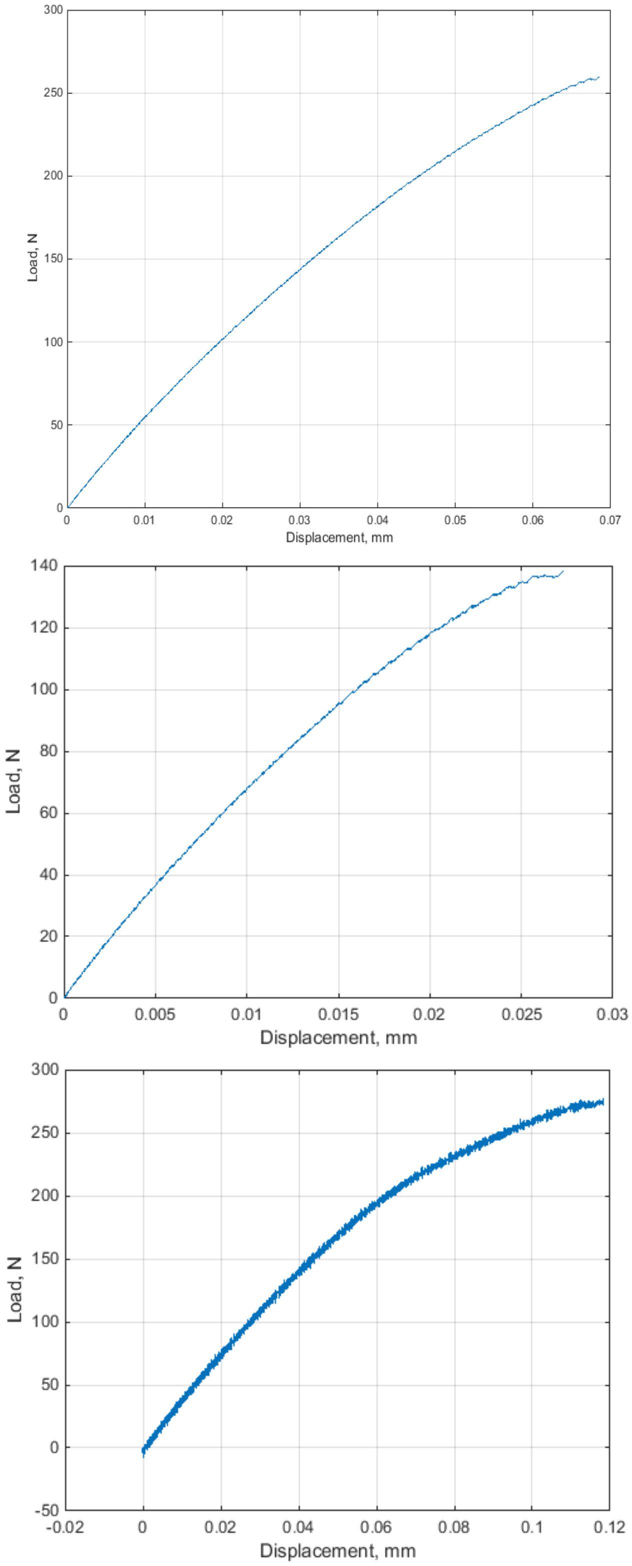


Figure A13.2: Load over Displacement under Shear Condition from Example Sample from each Group

Top Graph is the smooth group, the middle graph is the rough group, and the bottom graph that is the mixed group.

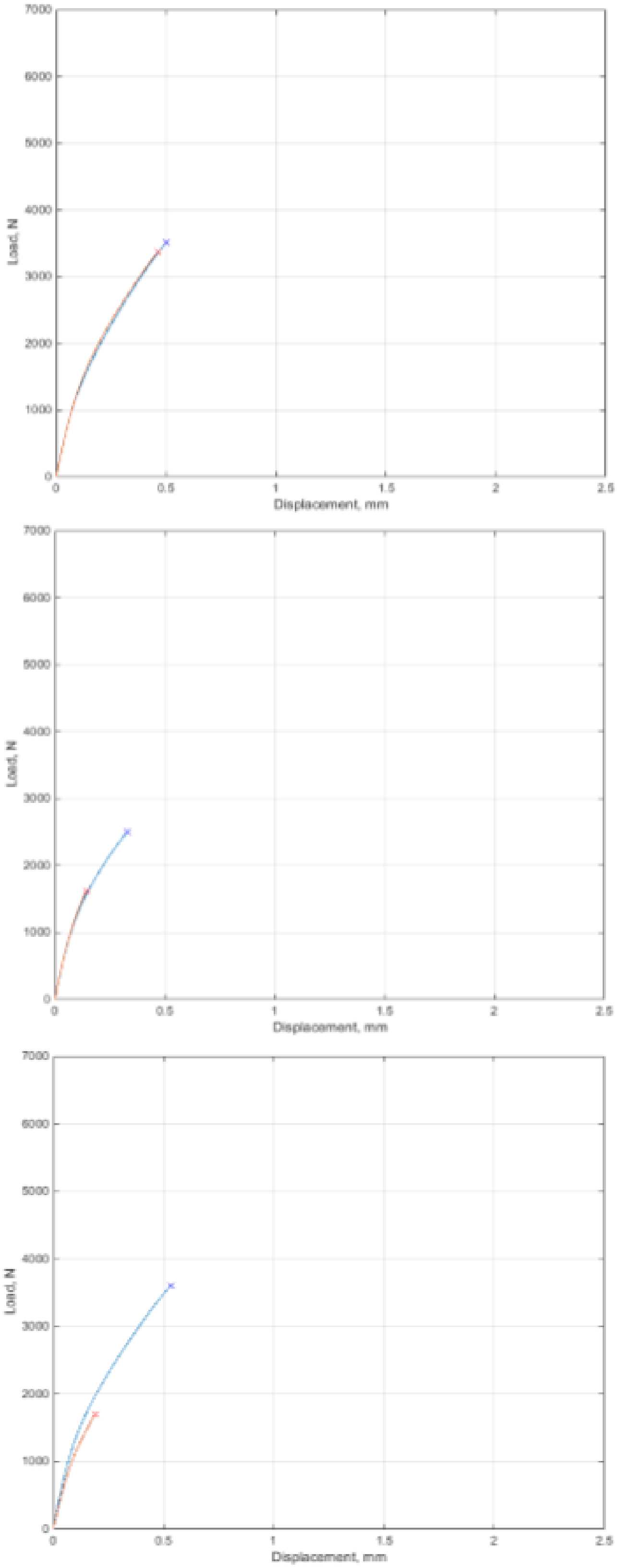


Figure A13.3: Batches 1 to 3 Load over Displacement Graph

The blue lines are the rough group and the red lines are the smooth group.

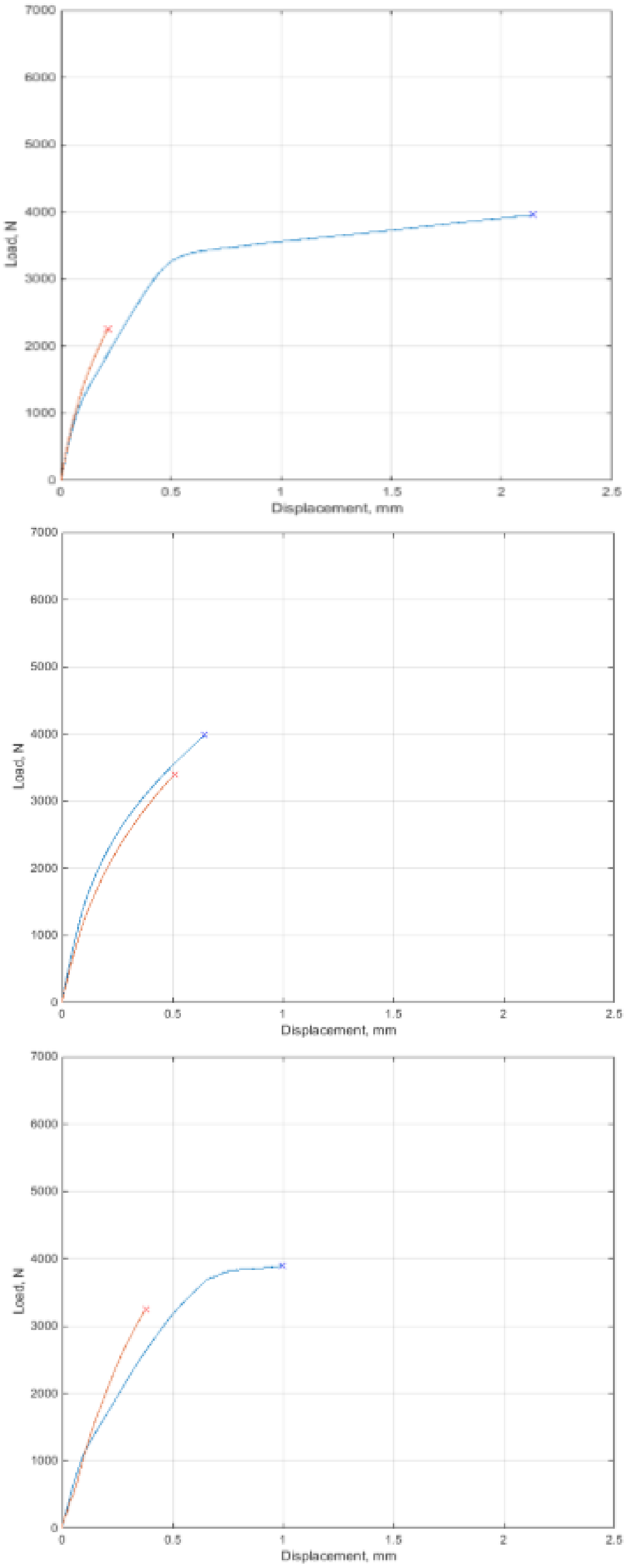


Figure A13.4: Batches 4 to 6 Load over Displacement Graph
The blue lines are the rough group and the red lines are the smooth group.

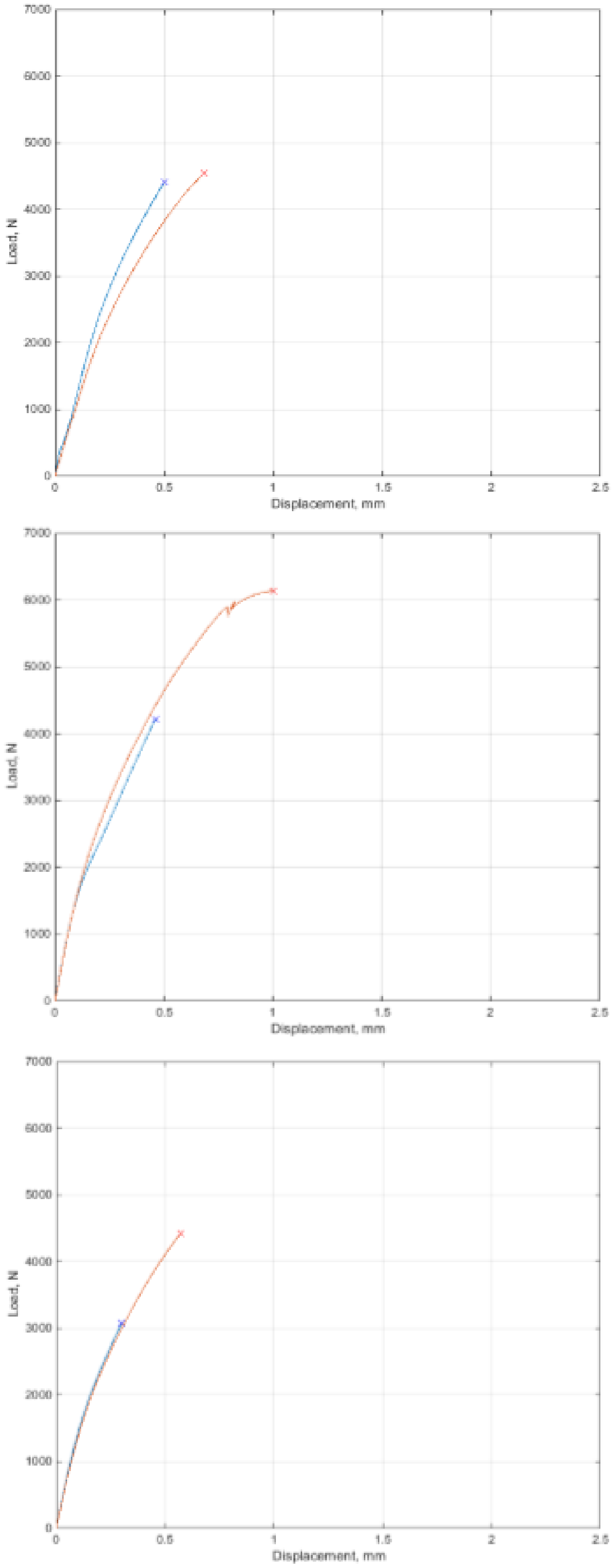


Figure A13.5: Batches 7 to 9 Load over Displacement Graph

The blue lines are the rough group and the red lines are the smooth group.

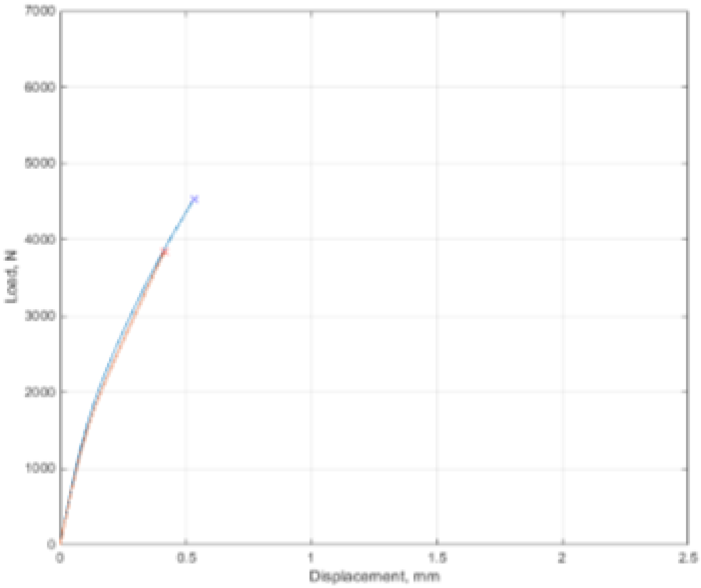


Figure A13.6: Batch 10 Load over Displacement Graph
The blue lines are the rough group and the red lines are the smooth group.

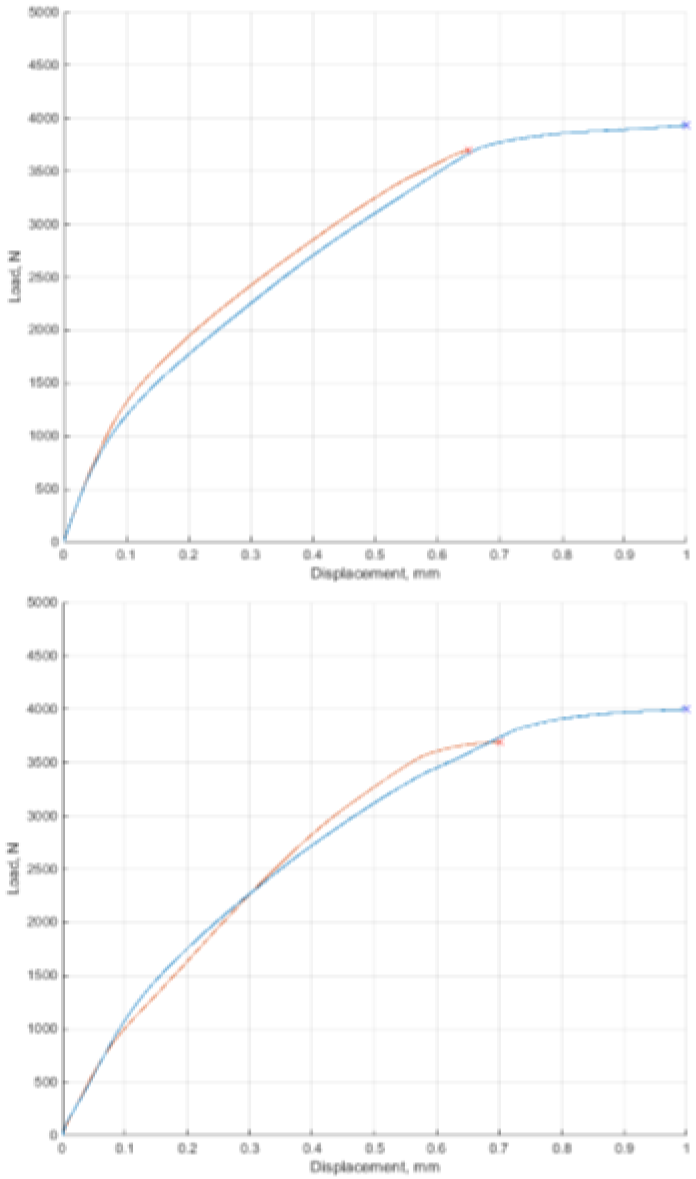


Figure A13.7: Mixed Batches 1 and 2 Load over Displacement Graph
The red lines are the smooth side first and the blue lines are the rough side first.

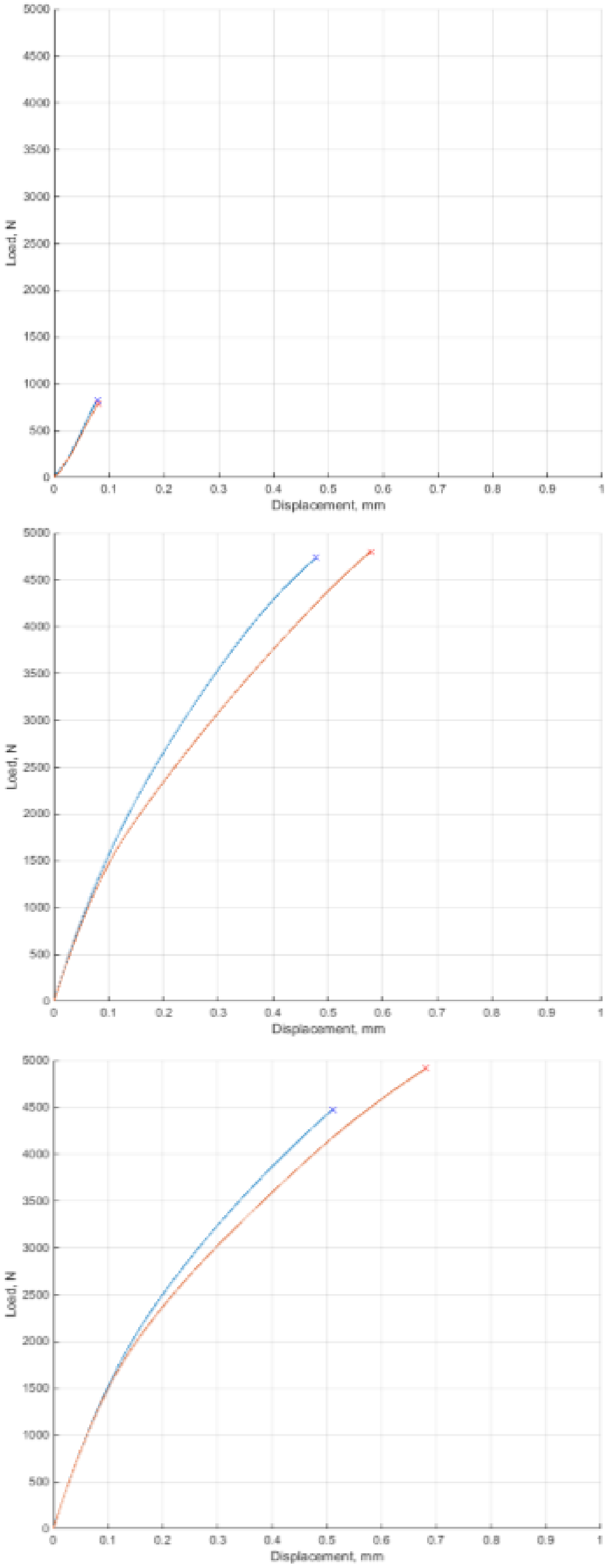
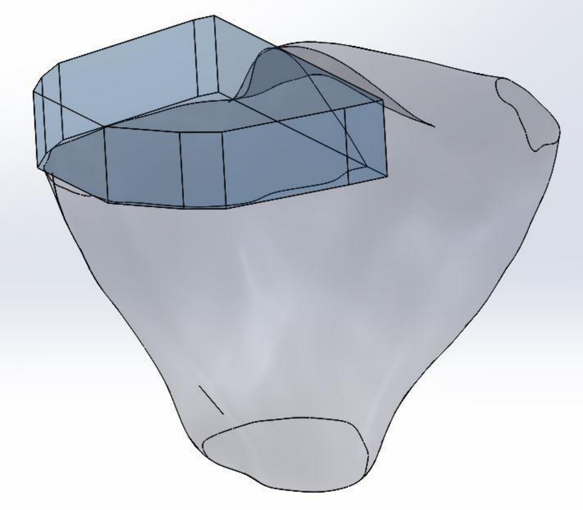
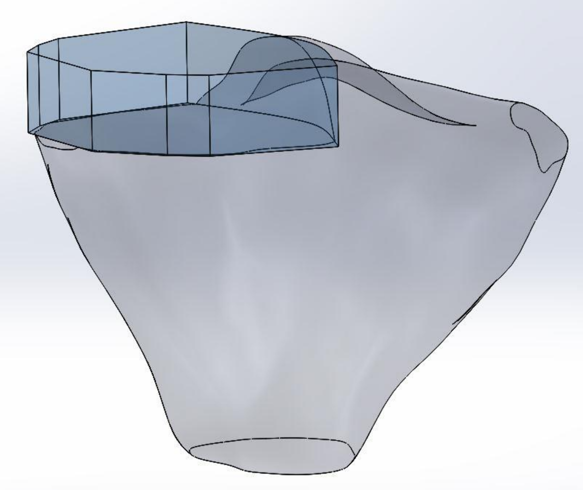
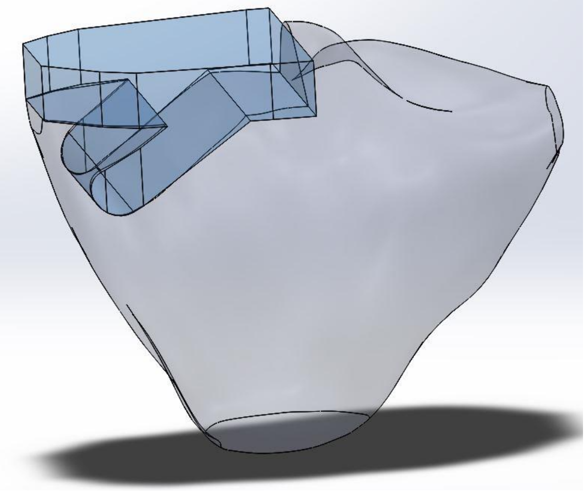
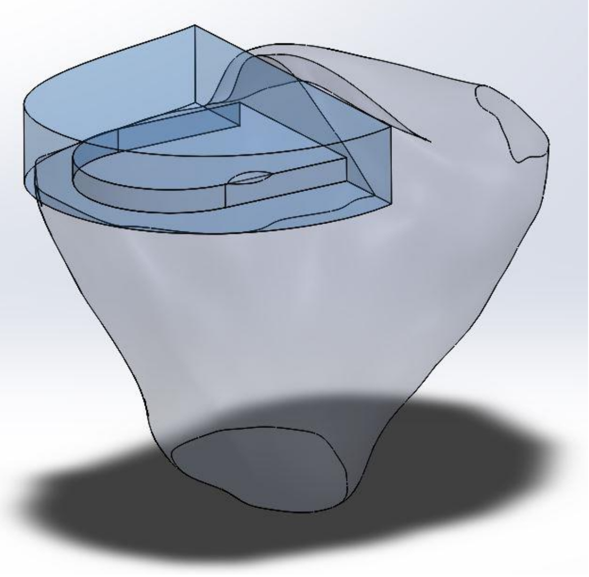


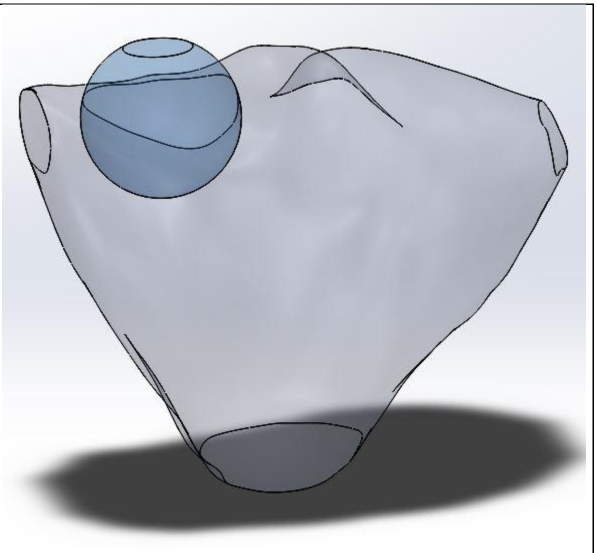
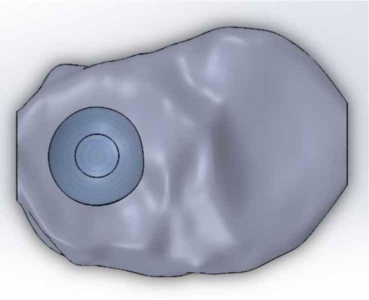
Figure A13.8: Mixed Batches 3 to 5 Load over Displacement Graph
The red lines are the smooth side first and the blue lines are the rough side first.

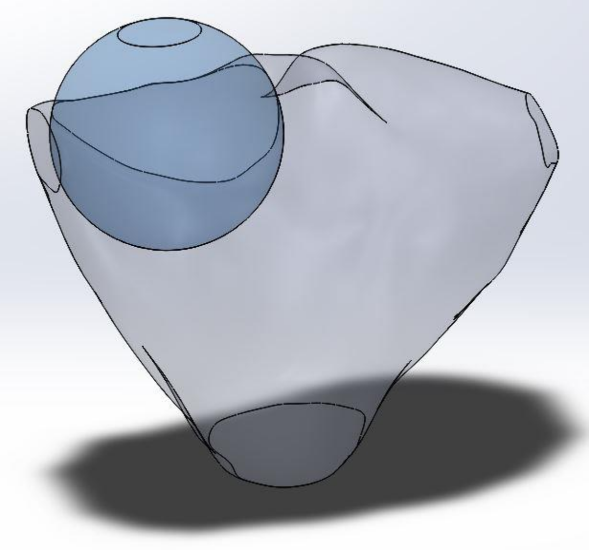
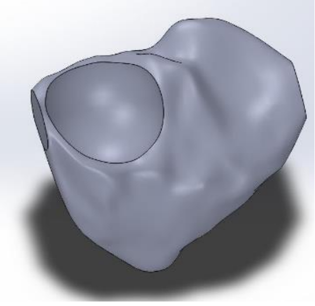
Appendix 14: Chapter 9 samples shapes

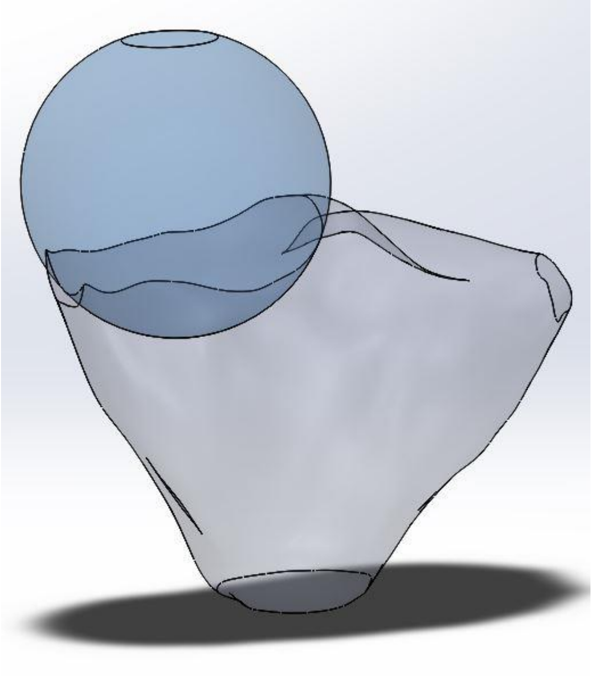
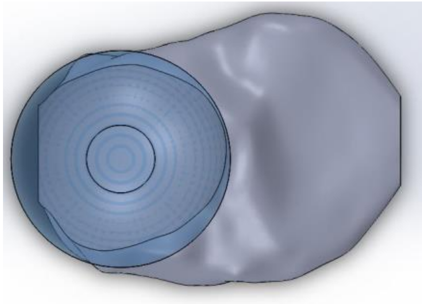
Table 7.1-1: Description of the Profiles

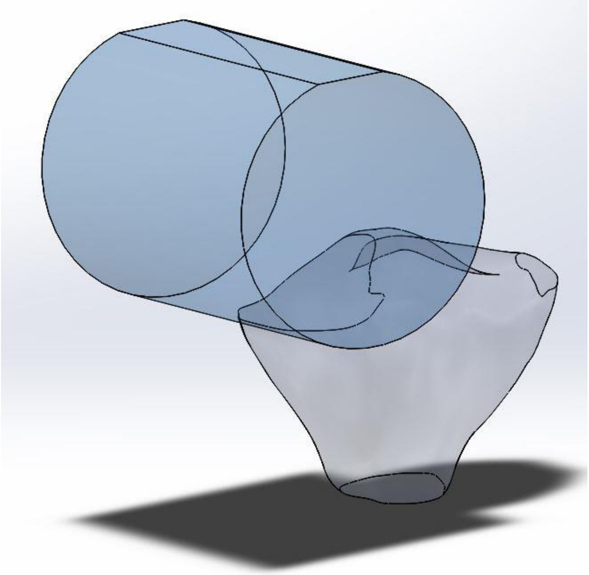
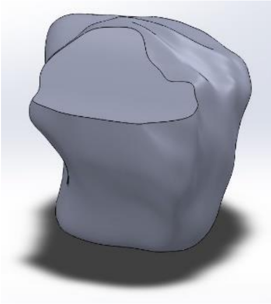
Profile name	Description	Figure reference
Flat	This profile is a block of metal that is flat top and bottom, the shape crudely follows the cut edge of the tibia. This is the most basic shape because it is two right-angle cuts on the tibia. It represents the load transfer of the standard UKR that do not include other features.	 Lateral anterior view
Flat Curve	This is like the flat profile, only the wall feature is different. The wall feature has a slight curved; the idea being that the curve could improve the shear loading conditions.	 Lateral anterior view

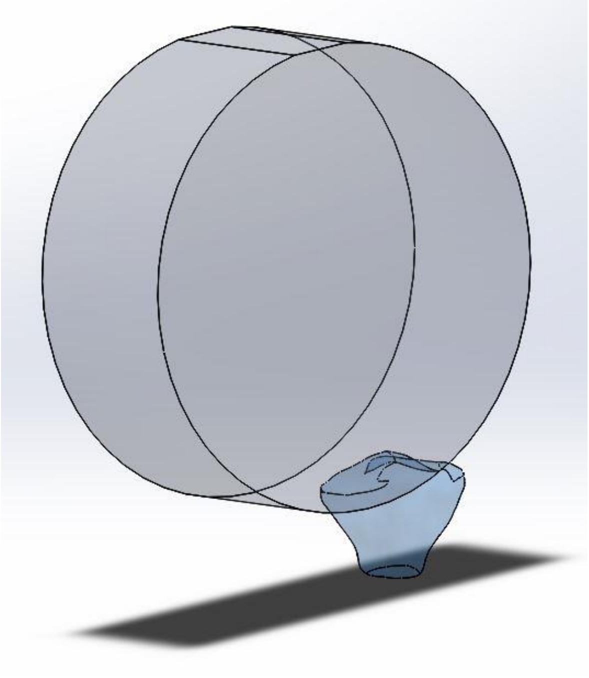
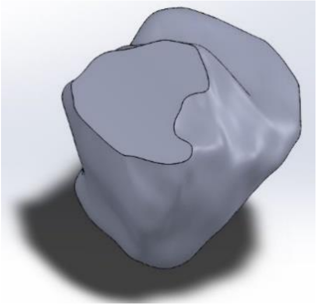
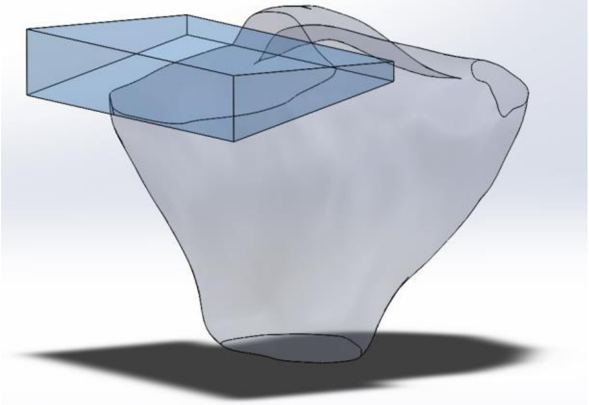
Undercut	Taking the flat profile, an anterior to posterior slot is included at a 30° angle from the distal flat surface. The reasoning is that the slant of the slot will directing the load towards the outer section of the tibia. In addition, the slot will give the profile a stronger fixation that also prevents lift-off.	 Lateral anterior view
Rim	The middle part of the flat profile is embossed so that there is a 'c'-like rim around the outside of the tibia. The reasoning being this would help direct the stress straight onto the outer part of the tibia.	 Lateral anterior view

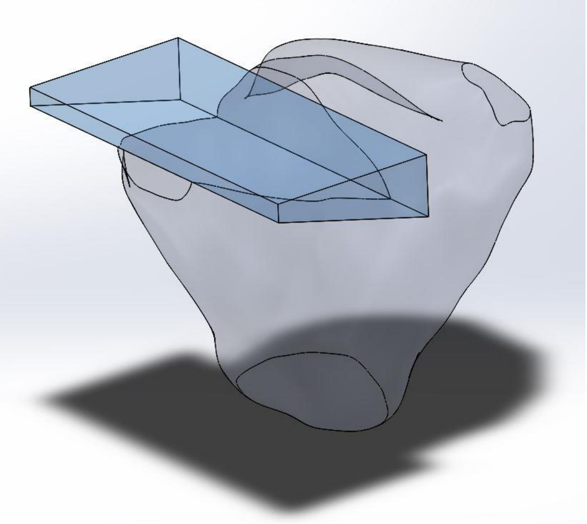
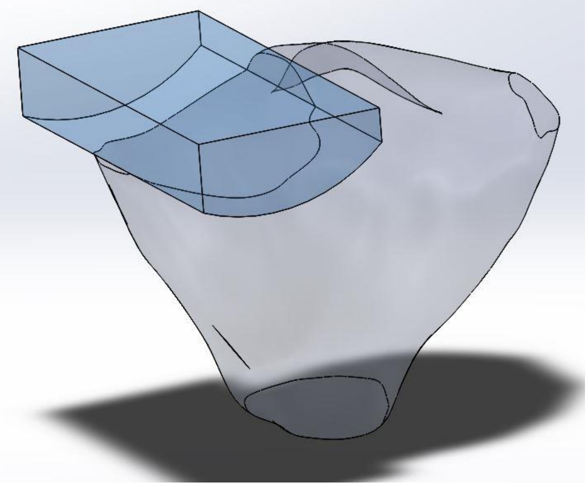
R10	In the middle of the lateral tibia plateau a rough hemisphere of radius 10 mm is removed and replaced with a sphere structure of 10mm radius. This allows two observations: to observe how a spherical like inlay prosthesis performs and to see what would happen if spherical features were added to undercarriage of an onlay prosthesis. The reasoning that this profile would be beneficial is the idea that the curve would equally distribute the stress across the surface just like an arch.	 Lateral anterior view  Proximal View

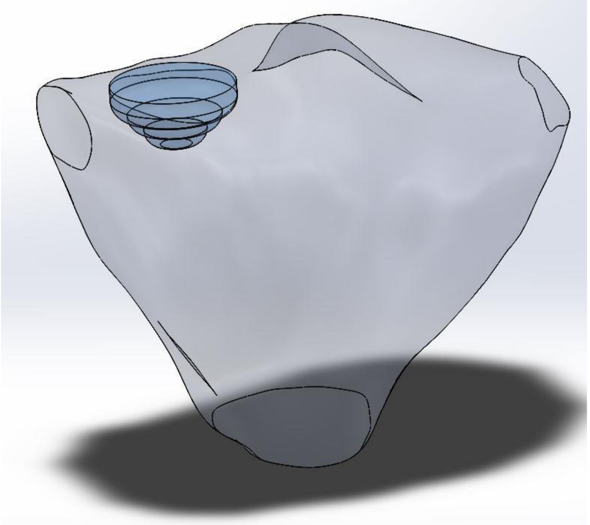
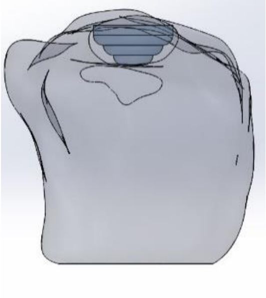
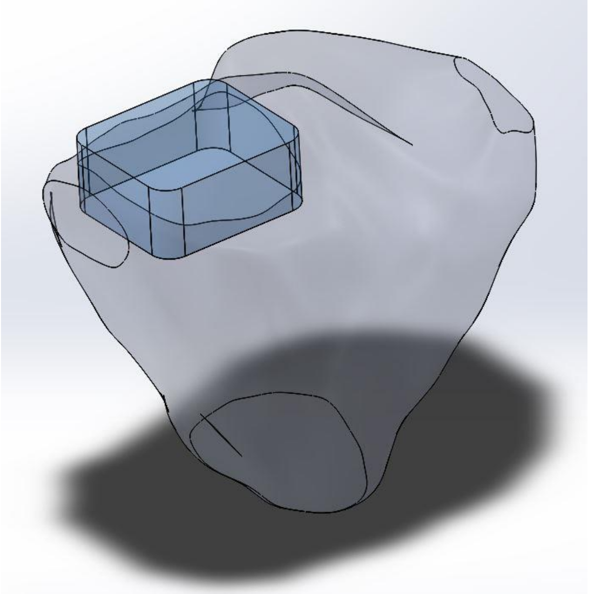
R15	This is same as the R10 profile but the sphere is 15mm in radius. It is to observe how a bigger sphere performs under the two conditions.	 Lateral anterior view  Proximal Lateral anterior view

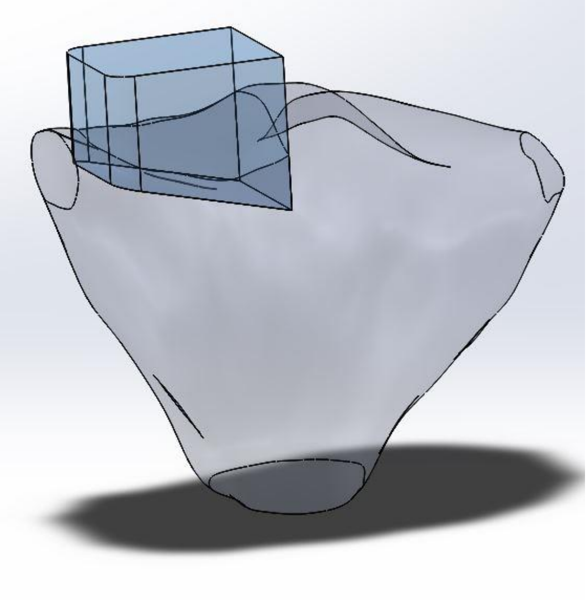
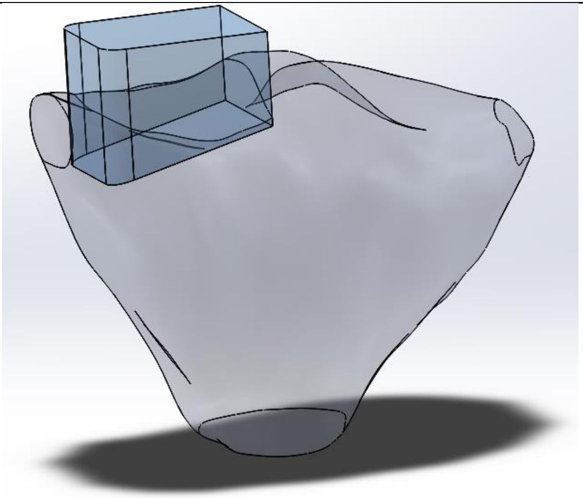
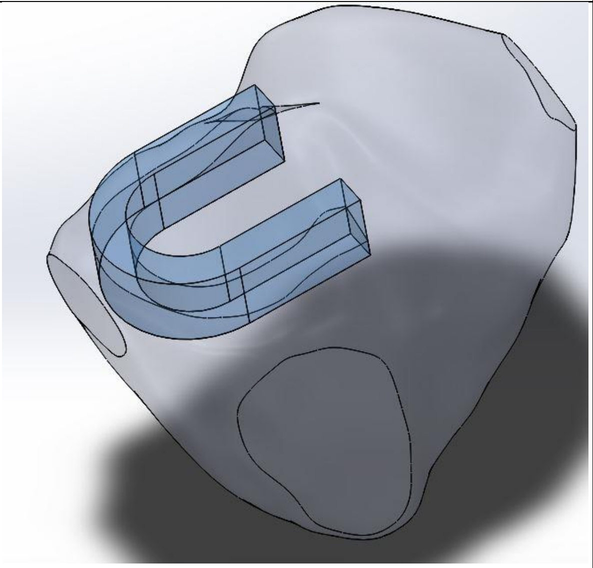
R20	The sphere structure had a radius of 20mm and it was placed on the tibia, like an onlay prosthesis. This type of profile can preserve more of the cortical bone possibly provide good load transfer.	 Lateral anterior view  Proximal View

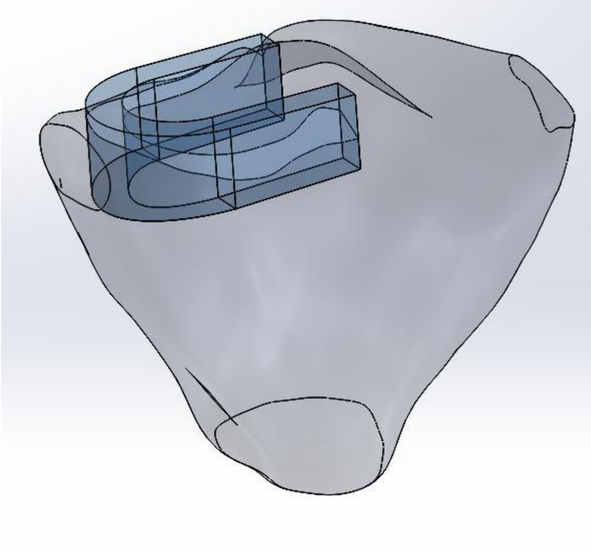
Rod 55	The rod is 55mm in radius and its axis is on the sagittal axis, is position on the tibia is like a onlay. The curve of the rod may provide an advantage of stress distribution in the tibia.	 Lateral anterior view  Lateral anterior view

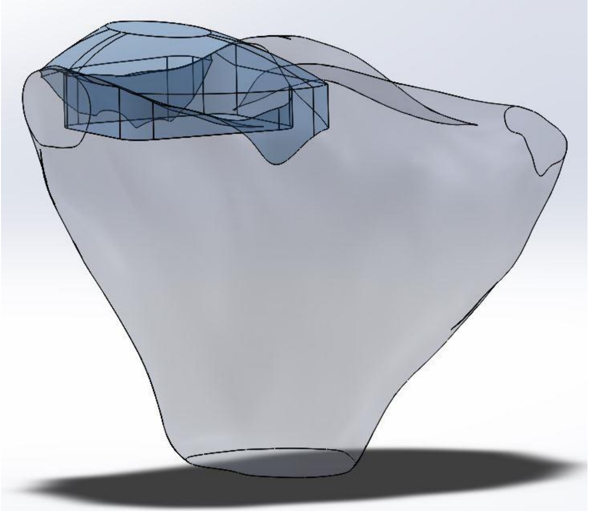
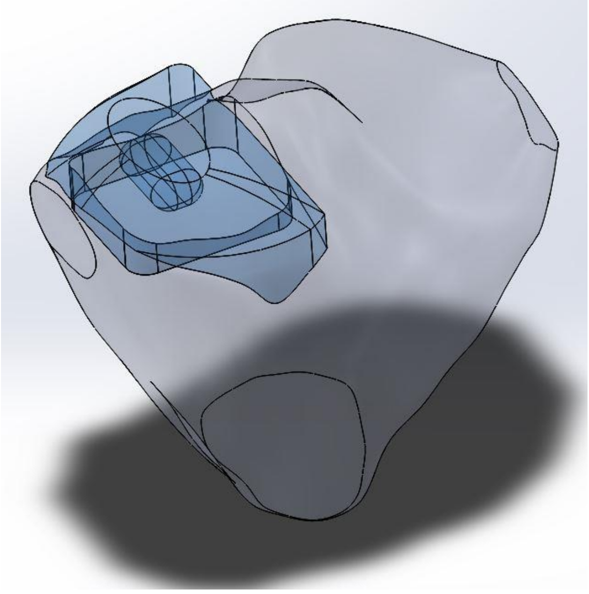
Rod 200	Like the Rod55 profile but the radius of the rod is 200mm. It is to observe how the different curve affects the von Mises stress in the tibia.	 Lateral anterior view  Proximal anterior view
Slant 10 L	This is a wedge like profile that is place on the lateral plateau similar to the rod structures. The highest point is in the middle of the tibia and the lowest point is on the lateral side of the tibia. This design assessed if a straight slant is good in distributing the stress to the surface of the tibia.	 Lateral anterior view

Slant 10 M	This is a wedge like profile that is place on the lateral plateau. It is the opposite to slant 10 L, as in the highest point is in the lateral side of the tibia and the lowest point is on the middle of the tibia. This design assessed if a straight slant is good in distributing the stress to the surface of the tibia.	 Lateral anterior view
Cone	The cone profile is similar to the slant 10 L but with a curve. The distal curve apex is located just off centre to the lateral edge. The purpose of this profile is to observe how having the distal curve apex lying in the tibial head will affect the stress patterns.	 Lateral anterior view

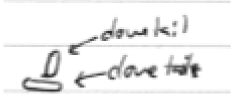
Dip	The dip is made up of 3 different size co-axial hemispheres, smallest 4mm in radius and the biggest is 8mm in radius. Each hemisphere should create a little step that may help with an equal loading of the stresses.	 Lateral anterior view  Lateral view
Inlay	This is a rudimentary representation of an inlay prosthesis. It is a square in the middle of the lateral plateau. This is to observe how stresses in an inlay prosthesis compares to the onlay prosthesis. This the starting point for improving the inlay profile.	 Lateral anterior view

Slant 10 I	This is the inlay type with the base slanting down to the middle of the tibia (i.e. the lowest point is medial side and the highest point is the lateral side). To observe if the slant of the recess improves the inlay stress distribution.	 Anterior lateral view
Slant 10 J	This is the inlay type with base slanting down to the lateral side of the tibia (i.e. the lowest point is the lateral side and the highest point is the medial side). To observe if the slant of the recess improves the inlay stress distribution.	 Anterior lateral view
Channels	The channel is in an 'C' shape that is just in from the perimeter of the tibial plateau; this is mostly an inlay type profile but could be integrated into an onlay prosthesis profile. The channel profile was investigated to observe if the stresses are directed more to the surface of the tibia.	

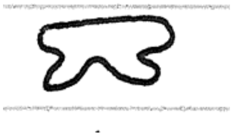
		Proximal anterior view
Channels Dip	This combines the channel and dip profile ideas. It is to observe if a channel has the lowest point the apex, the lateral of the tibia, will help direct the stresses to the outer surfaces of the tibia.	 Lateral anterior view

Arch	This was an abstract idea to improve the stress shielding in the inlay prosthesis that were observed. The inlay is attached to an arch that would act like the meniscus and direct the stress equally across the tibial plateau.	 Anterior lateral view
Arch with hole	This structure is the same as the arch profile but in the middle if the extruding 'meniscus acting' part of the profile there is a hole aimed to direct the stresses towards the perimeter of the tibia plateau.	 Proximal anterior view

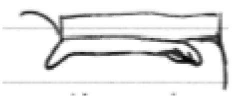
Appendix 15: Concepts Generated

Group D (Dovetail)			
First Matrix Appearance	Concept ID	Description	Sketches
1	D1	The tibial component flat with a female shape of a dovetail joint in the middle. The bone has the corresponding male shape of the dovetail. The dovetail is in the anterior to posterior direction.	
2	D1.2	The long dovetail is replaced with two smaller ones in the same direction. The material will need to be flexible to fit over the dovetails. It may reduce the attention needed for creating the dovetail shape.	
3	D1.3	Two off-plane parallel (female) plain slots replace the dovetail feature. The bone matches the component. This removed the complexity of creating the dovetail and the off-plane provides stability.	
1	D2	The tibial component flat with a female shape of a dovetail joint in the middle; mid-way of the dovetail is a (plain) slot in the perpendicular direction (medial to lateral) to increase stability.	
2	D2.2	The dovetail mention in D2 (and D1) is shorted to span half of the tibial component. In the other half of the component, another dovetail is placed but it is perpendicular to the other dovetail (medial to lateral). The 2nd dovetail increases stability.	
3	D2.3	The dovetail mention in D2 (and D1) is shorted to span half of the tibial component. In the other half of the component, a (plain) slot is present and it run perpendicular to the dovetail (medial to lateral). This is to reduce the difficulty of D2.2	

Group Pi (the tibial component initial looked like the legs in π)

First Matrix Appearance	Concept ID	Description	Sketches
1	Pi1	The tibial component looks like the legs in π. [picture]	
2	Pi1.2	Pi 1 is combined with group H idea (table) to help increase the loading patterns.	
2	Pi1.3	The undercut legs of Pi1 are shortened and does not extend past the cortical rim of the tibial. This is to reduced difficulty of making the undercuts and to increase anterior to posterior stability.	
2	Pi1.4	Pi1.2 and Pi1.3 are combined to take advantage of their benefits.	
3	Pi1.5	The table like structure of Pi1.2 is kept and the legs are replaced with 3 legs – 2 parallel in the anterior to posterior direction and one in the medial to lateral direction.	
3	Pi1.6	The table like structure of Pi1.2 and the lateral leg are kept and the medial leg is removed.	
3	Pi1.7	The table like structure of Pi1.2 is kept and the legs are replaced with 3 legs in a shape of a triangle– one in the anterior to posterior direction and the other two form the other equal side of the triangle.	

3	Pi1.8	The table like structure of Pi1.2 is kept and the legs are replaced with 3 legs –one in the medial to lateral direction and the other two make up a (equilateral) triangle.	
4	Pi1.9	The initial Pi1 structure is modified into one leg at angle (from the lateral side to the posterior side) and the flat surface is replaced with waves.	
1	Pi2	The middle part of the Pi legs are removed so the structure now has 4 legs that undercut the plateau.	

Group L (line/groove)			
First Matrix Appearance	Concept ID	Description	Sketches
1	L1	It has 3 evenly spaced out lines of a semi-circle cross-section (6mm diameter) running in the medial to lateral direction. This concept retains the fin feature of the MAKO.	
1	L2	It has 3 evenly spaced out lines of a semi-circle cross-section (6mm diameter) running in the medial to lateral direction. This concept does not have the fin feature of the MAKO.	
3	L2.3	L2 is combined with G7 concept.	
3	L2.4	Have the lines undercut the tibia at both ends.	
1	L3	It has 3 evenly spaced out lines of a semi-circle cross-section (3mm diameter) running in the medial to lateral direction. This concept does not have the fin feature of the MAKO.	

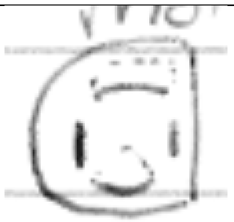
<table>
<tr><td colspan="4">Group A (Angular undercuts)</td></tr>
<tr><td>First Matrix Appearance</td><td>Concept ID</td><td>Description</td><td>Sketches</td></tr>
<tr><td>1</td><td>A1</td><td>The pegs are 3mm in diameter, short and at an angle on the tibial component. The tibial bone matches the corresponding shape.</td><td></td></tr>
<tr><td>3</td><td>A1.2</td><td>Is that same as A1 but the pegs are 6mm in diameter so a burr change is not needed.</td><td></td></tr>
<tr><td colspan="4">This idea is not strong by itself but is joined with other concepts to improve design lift.</td></tr>
</table>

<table>
<tr><td colspan="4">Group Q (for angled lines)</td></tr>
<tr><td>First Matrix Appearance</td><td>Concept ID</td><td>Description</td><td>Sketches</td></tr>
<tr><td>1</td><td>Q1</td><td>The lines on the tray form a ‘v’, the point of the ‘v’ is at the medial side of the tibial component. This concept retains the fin feature of the MAKO.</td><td></td></tr>
<tr><td>1</td><td>Q2</td><td>The lines on the tray form a ‘v’, the point of the ‘v’ is at the medial side of the tibial component. This concept does not have the fin feature of the MAKO.</td><td></td></tr>
<tr><td>3</td><td>Q2.3</td><td>The G7 concept is applied to Q2 concept.</td><td></td></tr>
<tr><td>1</td><td>Q3</td><td>The two lines of the ’v’ only touch on an edge.</td><td></td></tr>
</table>

Group W (waves in the undulating in the anterior to posterior plane)			
First Matrix Appearance	Concept ID	Description	Sketches
1	W1	The underside of the prosthesis has circular waves of 3mm in diameter undulating in the anterior to posterior plane.	
4	W1.2	The W1 concept is combined with the table feature of H3. So it is much like H3 but the surface is wavy	
4	W1.3	Adds the W1 wavy feature to concept S2.3 to try to improve stability together with good load transfer.	
1	W2	The underside of the prosthesis has circular waves of 6mm in diameter undulating in the anterior to posterior plane.	
3	W2.3	The G7 concept is applied to W2 concept.	
1	W3	The peaks of the waves are 3mm in diameter and the troughs of the wave are 6mm in diameter. Waves travels in the anterior to posterior plane.	

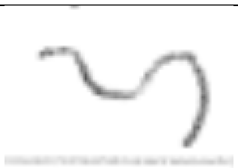
Group V (waves in the undulating in the medial to lateral plane)			
First Matrix Appearance	Concept ID	Description	Sketches
1	V1	The underside of the prosthesis has circular waves of 3mm in diameter undulating in the medial to lateral plane.	
4	V1.2	The wave style of V1 is added to H3 concept.	
1	V2	The underside of the prosthesis has circular waves of 6mm in diameter undulating in the medial to lateral plane.	
3	V2.3	The G7 concept is applied to V2 concept.	
1	V3	The peaks of the waves are 3mm in diameter and the troughs of the wave are 6mm in diameter. Waves travels in the medial to lateral plane.	

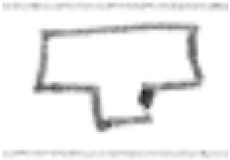
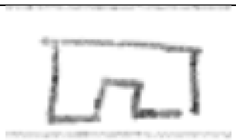
Group B (The waves are perpendicular that it produces interfering wave)			
First Matrix Appearance	Concept ID	Description	Sketches
2	B1	The underside of the prosthesis has circular waves of 6mm in diameter are perpendicular that it produces interfering waves.	
3	B1.2	The B1 concept is combined with G7 concept to try to improve the load transference.	
4	B1.3	This is the combination of B1 and S2.3 concepts.	

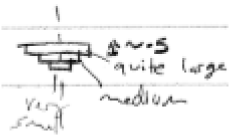
Group C (circle, often concentric)			
First Matrix Appearance	Concept ID	Description	Sketches
1	C1	The underside of the tibial component has 2 concentric rings are 6mm in diameter.	
1	C2	The underside of the tibial component has 4 number concentric rings are 3mm in diameter.	
1	C3	The underside of the tibial component has 3 number concentric rings are 3mm thick.	
1	C4	The underside of the tibial component has 2 number concentric circles are 3mm thick.	
2	C5	Has one 6mm ring at an angle so it under cuts the tibial bone slightly.	
4	C5.2	The circle shape in C5 is simplified to a square.	
2	C6	The concentric circle were made up of hemispherical bumps of 6mm.	
4	C8	A circle is added to the G7 concept.	

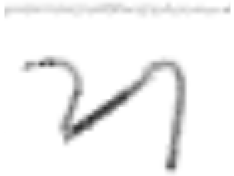
Group T (Toberone)			
First Matrix Appearance	Concept ID	Description	Sketches
1	T1	Along the medial edge of the prosthesis is a straight raised section, not dissimilar to a toberone without the bumps. This shape might be better at distributing the load and the shape is easier to make with a burr.	
1	T2	Has the same structure as above (T1) but the lateral edge is curved more.	
1	T3	Is the same as T1 with an additional curve towards the lateral side	
1	T4	The straight line in T1 now curves in a semi-circle with an outer radius of 9mm; the turning outer radius is 8.5mm.	
1	T5	The straight line in T1 now curves in a semi-circle with an outer radius of 9mm; the turning outer radius is 13mm.	
1	T6	Has a straight line on the lateral side of the tibial component, opposite to T1.	
2	T6.2	The T6 concept above with the addition of a	
1	T7	Has a straight line on the lateral side of the tibial component and the medial side of the line is curved, opposite to T2.	

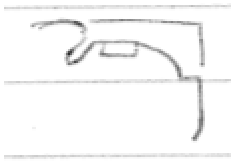
3	T8	Straight line in T1 is split in to two lines and a line in the medial to lateral direction is added in the middle of the tibial component.	
2	T9	The straight line is spilt into three peaks, more like toblerone.	

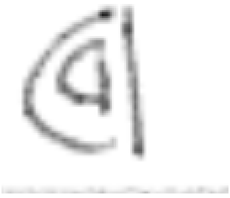
Group S (spherical)			
First Matrix Appearance	Concept ID	Description	Sketches
1	S1	There are 9 number of little spherical bumps of 6mm spaced out evenly.	
1	S2	The tibial component has a hemisphere of 12.25mm in radius.	
2	S2.2	The onlay component is turned into an inlay for possibly better load distribution.	
3	S2.3	The inlay concept in S2.2 but extended to cover the plateau like a onlay design.	
1	S3	The hemisphere of 12.25mm in diameter in concept S2 has the top cut off at 4mm.	
2	S3.2	The radius of the hemisphere is reduced to fit in two more.	
4	S3.3	An asymmetric shape instead of a circle (not far off a circle).	
1	S4	Two hemisphere of 7.5mm in radius.	

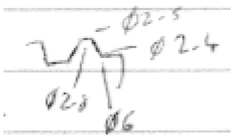
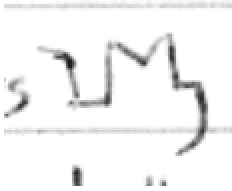
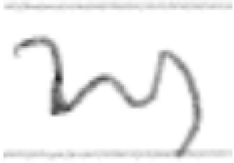
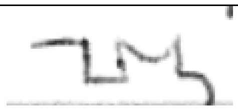
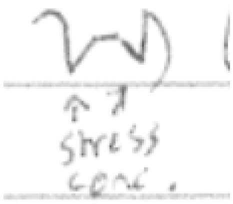
Group I (channel)			
First Matrix Appearance	Concept ID	Description	Sketches
1	I1	This is an inlay prosthesis idea, a line runs the middle of the polyelthene component in the anterior to posterior direction.	
2	I1.2	The channel is curved to the medial side of the tibial component.	
2	I1.3	The channel is angled from the medial side to the posterior side of the tibial component.	
1	I2	This is the inverse of I1 – the middle of the polyethene component is recessed into a dip in the anterior to posterior direction.	
2	I2.2	Is the inverse of I2 – the recess is in a curve following the medial side of the tibial component.	
2	I2.3	Is the inverse of I3 – the recess from the medial side to the posterior side of the tibial component.	

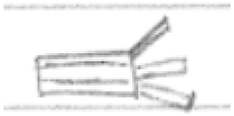
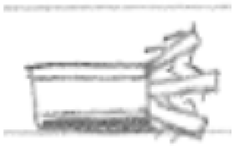
Group M (Dip)			
First Matrix Appearance	Concept ID	Description	Sketches
1	M1	The flat tibial component has a dip feature made up of 3 different size co-axial hemispheres, smallest 11mm and the biggest is 22mm in diameter.	
1	M2	The flat tibial component has a spiral feature of three turns. The smallest is 11mm in diameter and the biggest is 22mm.	
1	M3	It is the same as M1 but the bottom hemisphere is replaced with a rhombus like shape.	
1	M4	The features are the same as M3 but their height is halved.	
2	M5	The hemispheres in M1 are reduced in height to reduce the bone tissue loss.	
2	M6	M5 and H4 are combined. The curved channel of H4 gets deeper to the lateral edge of the tibial component.	
3	M7	It is like the M6 but it increases in depth in increments like steps rather than gradual.	

Group K (Slant)			
First Matrix Appearance	Concept ID	Description	Sketches
1	K1	The tibial component slants towards the middle of the tibia.	
2	K1.2	The tibial component slants away from the middle of the tibia.	
1	K2	The slanting tibial component slants towards the middle of the tibia and undercuts at the same angle.	
1	K3	T The slanting tibial component slants towards the middle of the tibia and in the middle of the tibia it has a horizontal undercut.	
2	K4	The tibial component slants away from the tibia, just before the rim is a line running from the anterior to the posterior and then the cut is horizontal.	
4	K4.2	It has the structure of K4 with the addition that the surface has the W wave feature.	

Group G (arch on the tray)			
First Matrix Appearance	Concept ID	Description	Sketches
1	G1	The tibial component is arched from the top middle of the tibia to the outer rim.	
1	G2	The degree of the curve is reduced.	
1	G3	Like the standard tibial component but the base is curved.	
1	G4	The opposite of G1	
1	G5	The opposite of G2	
1	G6	The opposite of G3	
2	G7	The structure is like G1 but the points of fixation are on the top most part and the outer most parts.	
4	G8	The tibial component is just a skimmed off the surface top have, at the edge of the tibia the component curves down and sits on the cortical rim.	
4	G8.1	Like G8 but on the medial side of the component, there is an undercut into the middle of the tibia.	
4	G8.2	Combined with the wave feature of B1 with G8 concept	
4	G8.3	This is the G8.1 concept with an extra line running anterior to posterior direction in the middle of the tibial component.	
6	G8.4		

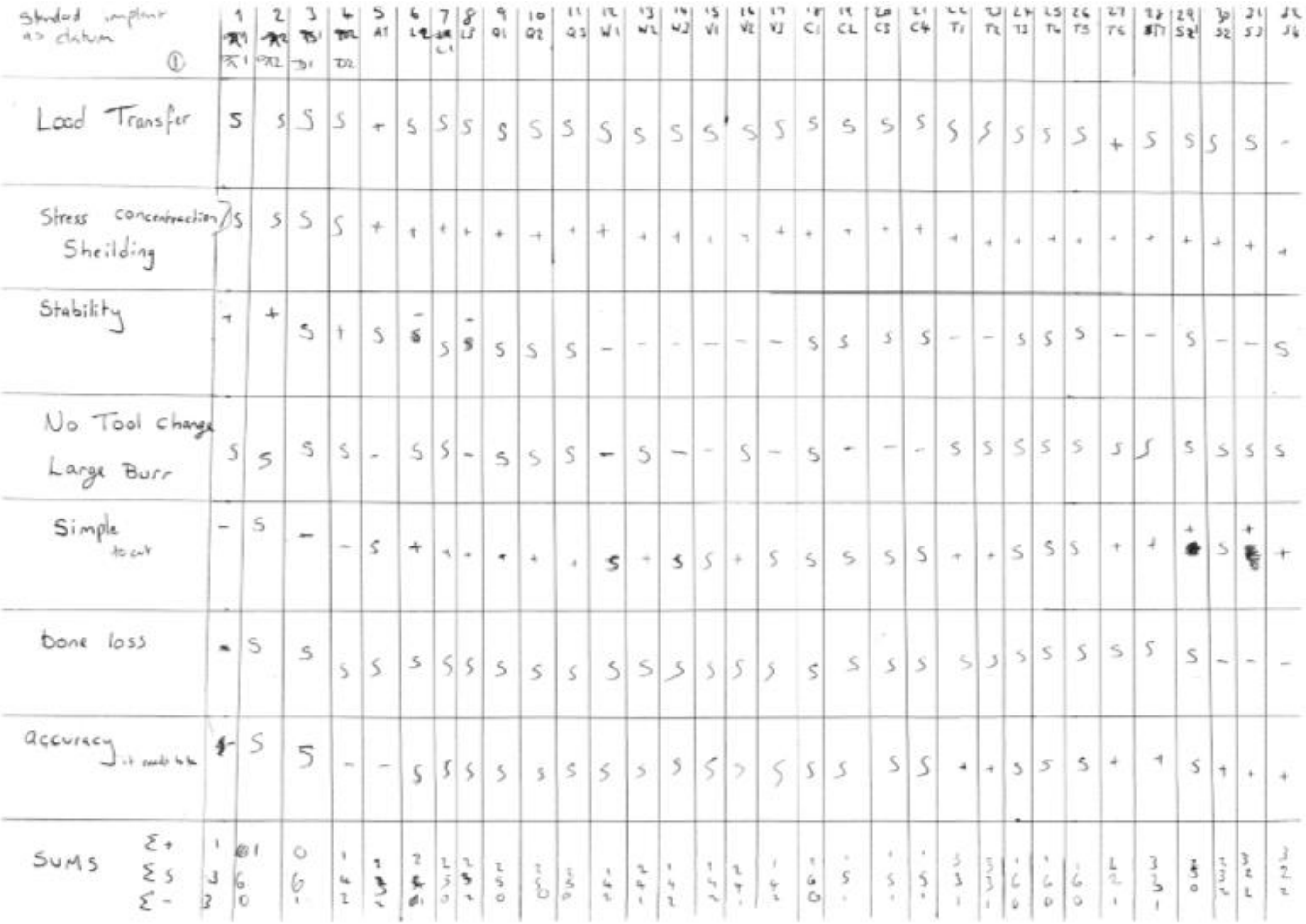
Group H (Table)			
First Matrix Appearance	Concept ID	Description	Sketches
1	H1	The surface of the tibia is skimmed off, the cortical bone is removed a little deeper and through the middle of the tibia. This done with a 3mm burr.	
1	H2	The surface of the tibia is skimmed off, the cortical bone is removed a little deeper and through the middle of the tibia. This done with a 6mm burr.	
1	H3	The surface of the tibia is skimmed off. A 'D' shape is grooved around the outer edge of the tibia. This is done with 3mm burr.	
4	H3.2	The surface of the tibia is skimmed off. A 'D' shape is grooved around the outer edge of the tibia that gets deeper towards the outer edge of the tibia. This is done with 3mm burr.	
1	H4	The surface of the tibia is skimmed off. A 'D' shape is grooved around the outer edge of the tibia. This is done with 6mm burr.	
4	H4.2	The surface of the tibia is skimmed off. A 'D' shape is grooved around the outer edge of the tibia that gets deeper towards the outer edge of the tibia. This is done with 6mm burr.	
Group U (Dome)			

First Matrix Appearance	Concept ID	Description	Sketches
1	U1	In the middle of the tibial component there is a recess of a cone, outer diameter of 20mm.	
2	U1.2	The dome in U1 is moved closer to the lateral side of the tibial component.	
1	U2	The difference between U2 and U1 them is very subtle, the main difference is U1 height is small than the U2.	
2	U2.2	The dome in U1 is moved closer to the lateral side of the tibial component.	
1	U3	Is the inverse of U1.	
2	U3.2	The U3 is turned into an inlay like design.	
1	U4	The middle of the flat tibial component there is a slopped recess in a rough ‘D’ shape.	
1	U5	The same shape in U4 but inversed.	
2	U5.2	The U3 is turned into an inlay like design.	
1	U6	It is similar to U5 with a slant.	

Group R (Additional)			
First Matrix Appearance	Concept ID	Description	Sketches
Na	R1	Have something like the MAKO fins on the medial wall to encourage fixation.	
Na	R2	Have lines running along the wall to improve cement fixation.	
6	R3	Structures for attaching the prosthesis to the wall similar to dental implant buttresses.	
6	R4	A screw with spokes fixing the prosthesis to the cut wall.	
6	R4.2	Have the screw and spokes mention in R4 to be barbed.	
6	R5	Have a curved cut medial wall.	
Na	R6	A combination of R5 with either R4 or R4.2.	
Na	F1	The feature in the G family combined with 2 anterior and posterior lines and one line at an angle.	
Na	F2	The feature in the G family combined with W, V and B waves plus an angled line for extra stability.	
4	F3	The feature in the G family combined with an 'S' shaped line.	

Appendix 16: Design Matrices

Matrix 1a



Standard implant as datum ①	1 TX1	2 TX2	3 TS1	4 TS2	5 A1	6 L2	7 L1	8 L3	9 Q1	10 Q2	11 Q3	12 W1	13 W2	14 W3	15 V1	16 V2	17 V3	18 C1	19 C2	20 C3	21 C4	22 T1	23 T2	24 T3	25 T4	26 T5	27 T6	28 ST	29 S1	30 S2	31 S3	32 S4
Load Transfer	S	S	S	S	+	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	+	S	S	S	S	-
Stress concentration Sheilding	S	S	S	S	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Stability	+	+	S	+	S	- S	S	- S	S	S	S	-	-	-	-	-	-	S	S	S	S	-	-	S	S	S	-	-	S	-	-	S
No Tool Change Large Burr	S	S	S	S	-	S	S	-	S	S	S	-	S	-	-	S	-	S	-	-	-	S	S	S	S	S	S	S	S	S	S	S
Simple to cut	-	S	-	-	S	+	+	+	+	+	+	S	+	S	S	+	S	S	S	S	S	+	+	S	S	S	+	+	+	S	+	+
bone loss	-	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	-	-	-
accuracy	-	S	S	-	-	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	+	+	S	S	S	+	+	S	+	+	+
SUMS Σ+	1	1	0	1	2	2	2	2	2	2	2	1	2	1	1	2	1	1	1	1	1	3	3	1	1	1	4	3	2	2	3	3
ΣS	3	6	6	4	3	4	5	3	5	5	5	4	4	4	4	4	4	6	5	5	5	3	3	6	6	6	2	3	5	3	2	2
Σ-	3	0	1	2	2	1	0	2	0	0	0	2	1	2	2	1	2	0	1	1	1	1	1	0	0	0	1	1	0	2	2	2

Matrix 1b

standard implant as datum ①	33 I1	34 I2	35 M1	36 M2	37 M3	38 M4	39 U1	40 U2	41 U3	42 U4	43 U5	44 U6	45 K1	46 K2	47 K3	48 G1	49 G2	50 G3	51 G4	52 G5	53 G6	54 H1	55 H2	56 H3	57 H4
Load Transfer	S	S	S	S	S	S	S	S	− +	+	−	−	−	−	−	+	S	S	−	−	−	+	+	+	+
Stress Concentration/ Sheilding	+	+	+	+	+	+	+	+	+	+	+	+	+	S	S	+	+	+	+	+	+	+	+	+	+
Stability	−	−	− +	S	S	S	S	S	+	+	+	+	−	−	S	−	−	−	S	S	S	S	S	S	S
No Tool Change Large Bur	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	−	S	−	S
Simple	+	+	+	+	+	+	+ S	+	−	S	−	+ +	+	S	S	+	+	+	+	+	+	S	S	S	S
Bone loss	S	S	−	−	−	−	+	+	+	+	+	+	+	S	S	S	S	S	S	S	S	+ S	S	+	+
Accuracy	+	+	+	+	+	+	+	+	S	+	−	+	+	S	−	+	+	+	+	+	+	S	S	S	S
Sums Σ + Σ S Σ −	3 3 1	3 3 1	3 2 2	3 3 1	3 3 1	2 3 1	4 1 0	4 3 0	1 2 2	5 2 0	3 1 3	5 1 1	4 1 2	0 5 2	0 5 2	4 2 1	3 2 1	3 3 1	3 3 1	3 3 1	3 3 1	3 3 1	2 5 0	3 3 1	3 4 0

observation of the sums (2)

the most + are the undercut Group

the most neutral is close and Pi, concentric, tolerance

So the [illegible] where the pegs are switched to barred lines.

the best promising is 39 1 A 43
[illegible]

Matrix 2a

Standard implant as datum ②	∝ 1·2	∝ 1·3	∝ 2	D 1·2	D 2·2	A 1	L 2	Q 1	W 2	V 2	B 1	C 1	C 5	C 6	T 1	T 6	T 8	T 9	T 6·2	S 1	S 2·2	S 3·2	I 1·2	I 1·3	I 2·2	I 2·3	M 5	M 6	U 1·2	U 2·2	U 3·2	U 5·2
perceived Load Transfer	+	S	S	S	S	+	S	S	S	S	S	S	S	S	S	+	S	S	+	S	+	S	S	S	S	S	+	+	+	+	+	+
Stress Concentration/ sheilding	+	S	S	S	S	+	+	+	+	+	+	+	S	+	+	+	+	S	+	+	+	+	+	+	+	+	+	+	+	+	S	S
Stabitity	S	S	S	S	S	S	-	~~S~~ -	-	-	~~S~~ -	~~S~~ -	S	-	-	-	-	-	-	~~S~~ -	-	-	-	-	-	-	-	-	-	-	-	+
No Tool Change Large Burr	S	S	S	S	S	-	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Simple	~~S~~ -	-	-	-	~~S~~ -	S	+	+	+	+	+	S	-	+	+	+	+	S	S	+	+	+	+	+	+	+	+	S	S	S	+	+
Bone Loss	-	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	-	+	+	+	+	+
Accuracy	S	S	S	S	S	-	S	S	S	S	S	S	S	S	+	+	S	S	S	S	+	+	S	S	S	S	+	S	+	+	+	+
Sums Σ+ ΣS Σ-	2 3 2	0 6 1	0 6 1	0 6 1	0 6 1	2 3 2	2 4 1	2 4 1	2 4 1	2 4 1	2 4 1	1 5 1	0 6 1	2 4 1	3 3 1	4 2 1	2 4 1	0 6 1	2 4 1	2 4 1	4 2 1	3 3 1	2 4 1	2 4 1	2 4 1	2 4 1	4 1 2	3 3 1	4 2 1	4 2 1	4 2 1	5 2 0

Matrix 2b

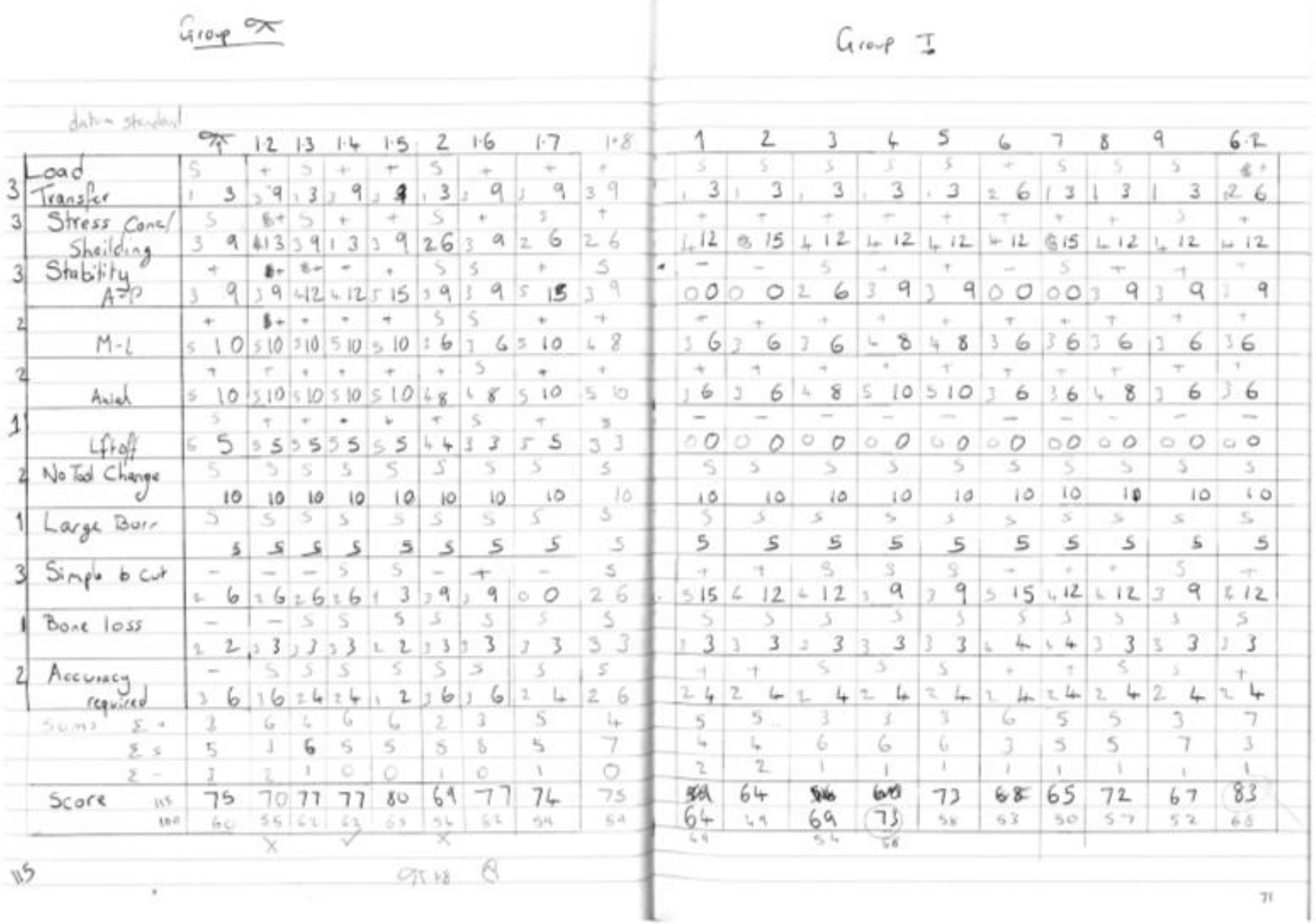
Standard implant as datum ②	K 12	K 6	G 1	G 7	H 2	H 6	π 16
perceived Load Transfer	+	+	+	+	+	+	+
Stress Concentration/ Sheilding	+	+	+	+	+	+	+
✗ Stability	–	–	–	–	S	S	+
No Tool change Large Burr	S	S	S	S	S	S	S
Simple to Cut	+	+	+	+	S	S	S
Bone Loss	+	+	S	+S	S	+ S	S
Accuracy required	+	+	+	+	S	S	S
Sums Σ+	5	5	4	4	2	3	3
ΣS	1	1	2	2	5	4	4
Σ-	1	1	1	1	0	0	0

first glance

- π, D and C, are perform slightly worse than implant

undercut and slant perform slightly better

Matrix 3a



Group π

Group I

datum standard

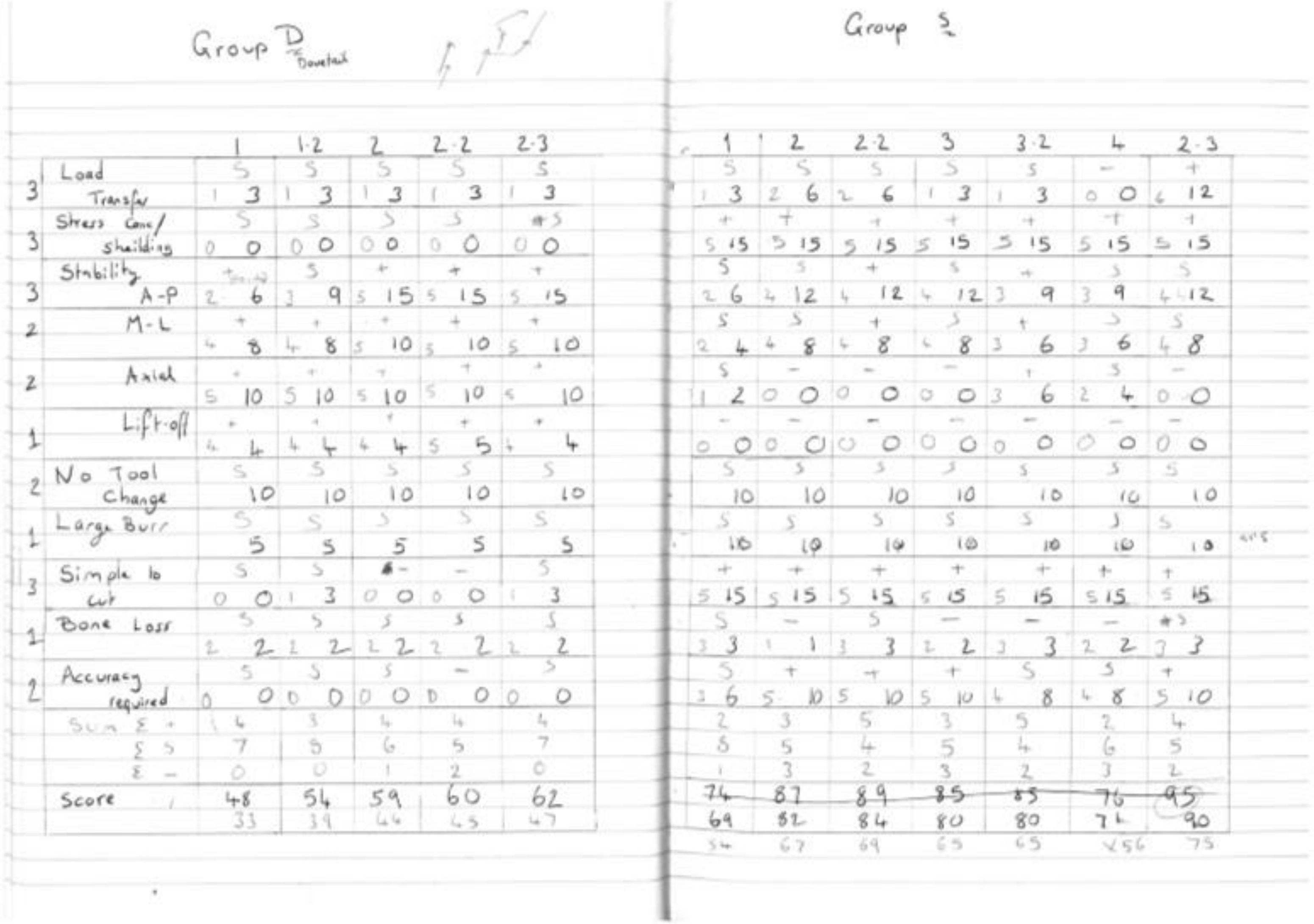
		π	1·2	1·3	1·4	1·5	2	1·6	1·7	1·8	1	2	3	4	5	6	7	8	9	6·2
3	Load Transfer	S 1 3	+ 3 9	S 1 3	+ 3 9	+ 3 9	S 1 3	+ 3 9	+ 3 9	+ 3 9	S 1 3	S 1 3	S 1 3	S 1 3	S 1 3	+ 2 6	S 1 3	S 1 3	S 1 3	+ 2 6
3	Stress Conc/ Sheilding	S 3 9	S+ 4 13	S 3 9	+ 1 3	+ 3 9	S 2 6	+ 3 9	S 2 6	+ 2 6	+ 4 12	+ 5 15	+ 4 12	+ 4 12	+ 4 12	+ 4 12	+ 5 15	+ 4 12	S 4 12	+ 4 12
3	Stability A-P	+ 3 9	S+ 3 9	S+ 4 12	+ 4 12	+ 5 15	S 3 9	S 3 9	+ 5 15	S 3 9	− 0 0	− 0 0	S 2 6	+ 3 9	+ 3 9	− 0 0	S 0 0	+ 3 9	+ 3 9	+ 3 9
2	M-L	+ 5 10	S+ 5 10	+ 5 10	+ 5 10	+ 5 10	S 3 6	S 3 6	+ 5 10	+ 4 8	+ 3 6	+ 3 6	+ 3 6	+ 4 8	+ 4 8	+ 3 6	+ 3 6	+ 3 6	+ 3 6	+ 3 6
2	Axial	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 4 8	S 4 8	+ 5 10	+ 5 10	+ 3 6	+ 3 6	+ 4 8	+ 5 10	+ 5 10	+ 3 6	+ 3 6	+ 4 8	+ 3 6	+ 3 6
1	Liftoff	S 5 5	+ 5 5	+ 5 5	+ 5 5	+ 5 5	+ 4 4	S 3 3	+ 5 5	S 3 3	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0
2	No Tool Change	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10
1	Large Burr	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5
3	Simple to cut	− 2 6	− 2 6	− 2 6	S 2 6	S 1 3	− 3 9	+ 3 9	− 0 0	S 2 6	+ 5 15	+ 4 12	S 4 12	S 3 9	S 3 9	+ 5 15	+ 4 12	+ 4 12	S 3 9	+ 4 12
1	Bone loss	− 2 2	− 3 3	S 3 3	S 3 3	S 2 2	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	S 4 4	S 4 4	S 3 3	S 3 3	S 3 3
2	Accuracy required	− 3 6	S 3 6	S 2 4	S 2 4	S 1 2	S 3 6	S 3 6	S 2 4	S 2 6	+ 2 4	+ 2 4	S 2 4	S 2 4	S 2 4	+ 2 4	+ 2 4	S 2 4	S 2 4	+ 2 4
Sums	Σ +	3	6	4	6	6	2	3	5	4	5	5	3	3	3	6	5	5	3	7
	Σ S	5	3	6	5	5	8	8	5	7	4	4	6	6	6	3	5	5	7	3
	Σ −	3	2	1	0	0	1	0	1	0	2	2	1	1	1	1	1	1	1	1
Score	115	75	70	77	77	80	69	77	74	75	[illegible]	64	[illegible]	[illegible]	73	68	65	72	67	83
	100	60	55	62	63	65	56	62	54	59	64	49	69	73	58	53	50	57	52	68
			X		✓		X				49		54	58						

115

π 1·8 8

71

Matrix 3b



Group D
= Dovetail

		1	1·2	2	2·2	2·3
3	Load Transfer	S 1 3	S 1 3	S 1 3	S 1 3	S 1 3
3	Stress Conc/ shailding	S 0 0	S 0 0	S 0 0	S 0 0	*S 0 0
3	Stability A-P	+ 2 6	S 3 9	+ 5 15	+ 5 15	+ 5 15
2	M-L	+ 4 8	+ 4 8	+ 5 10	+ 5 10	+ 5 10
2	Axial	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10
1	Lift-off	+ 4 4	+ 4 4	+ 4 4	+ 5 5	+ 4 4
2	No Tool Change	S 10	S 10	S 10	S 10	S 10
1	Large Burr	S 5	S 5	S 5	S 5	S 5
3	Simple to cut	S 0 0	S 1 3	*− 0 0	− 0 0	S 1 3
1	Bone Loss	S 2 2	S 2 2	S 2 2	S 2 2	S 2 2
2	Accuracy required	S 0 0	S 0 0	S 0 0	− 0 0	S 0 0
	Sum Σ +	4	3	4	4	4
	Σ S	7	5	6	5	7
	Σ −	0	0	1	2	0
	Score	48 33	54 39	59 44	60 45	62 47

Group S

1	2	2·2	3	3·2	4	2·3
S 1 3	S 2 6	S 2 6	S 1 3	S 1 3	− 0 0	+ 6 12
+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15
S 2 6	S 4 12	+ 4 12	S 4 12	+ 3 9	S 3 9	S 4 12
S 2 4	S 4 8	+ 4 8	S 4 8	+ 3 6	S 3 6	S 4 8
S 1 2	− 0 0	− 0 0	− 0 0	+ 3 6	S 2 4	− 0 0
− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0
S 10	S 10	S 10	S 10	S 10	S 10	S 10
S 10	S 10	S 10	S 10	S 10	S 10	S 10
+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15
S 3 3	− 1 1	S 3 3	− 2 2	− 3 3	− 2 2	*S 3 3
S 3 6	+ 5 10	+ 5 10	+ 5 10	S 4 8	S 4 8	+ 5 10
2	3	5	3	5	2	4
8	5	4	5	4	6	5
1	3	2	3	2	3	2
~~74~~ 69	~~87~~ 82	~~89~~ 84	~~85~~ 80	~~85~~ 80	~~76~~ 71	~~95~~ 90
54	67	69	65	65	√56	75

Matrix 3c

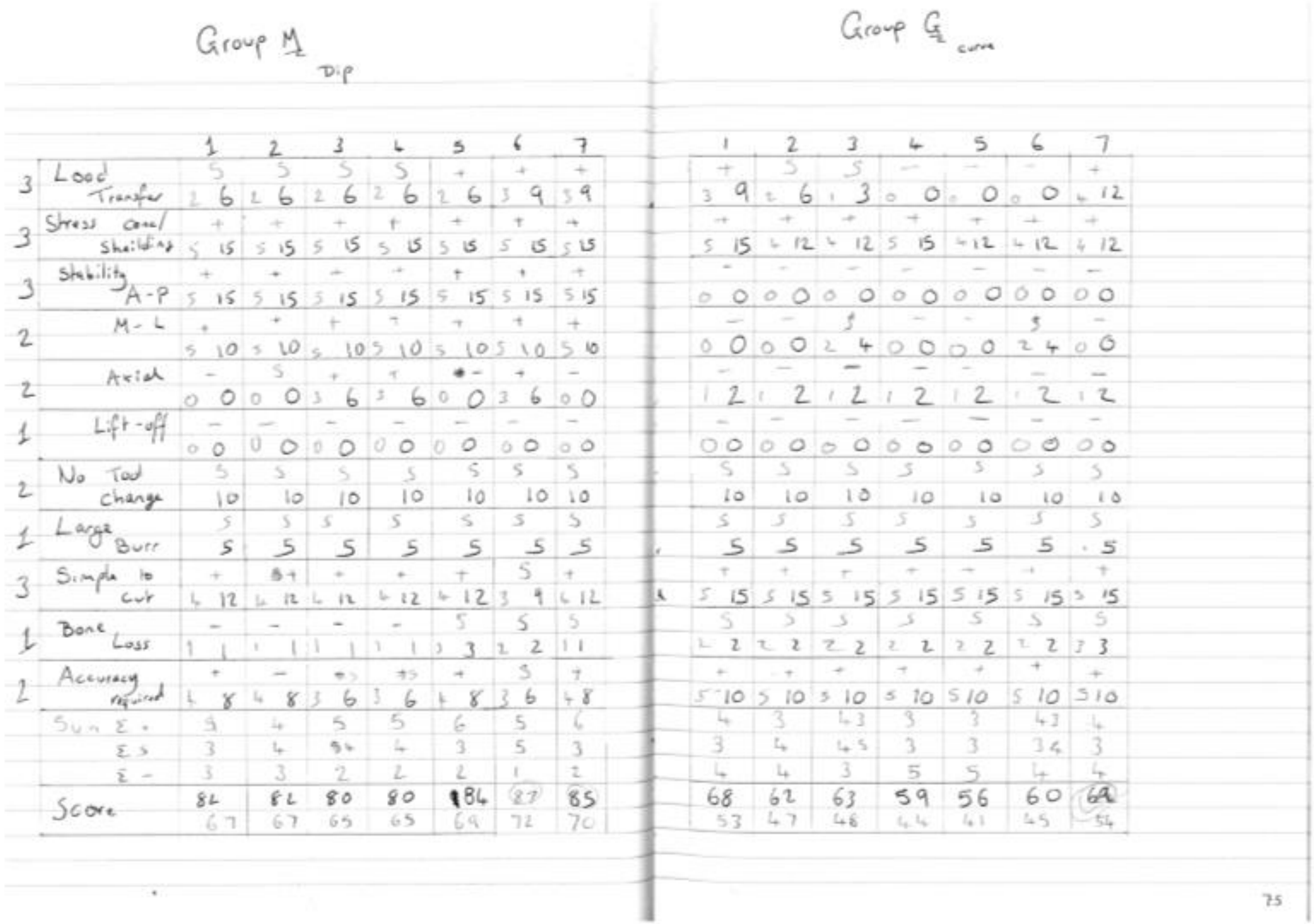
Group $C_{2\,\text{scratch}}$

		1	2	3	4	5	6
3	Load Transfer	S 1 3	S 1 3	S 1 3	S 1 3	S 1 3	S 1 3
3	Stress conc/ Sheilding	+ 5 15	+ 5 15	+ 5 15	+ 5 15	S 3 9	+ 5 15
3	Stability A-P	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	S 2 6
2	M-L	S + 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10	S 2 4
2	Axial	− 0 0	− 0 0	− 0 0	− 0 0	+ 3 6	S 1 2
1	Lift-off	− 0 0	− 0 0	− 0 0	− 0 0	S 3 3	− 0 0
2	No Tool change	S 10	− 0	− 0	− 0	S 10	S 10
1	Large Burr	S 5	− 0	− 0	− 0	S 5	S 5
3	Simple to cut	+ 3 9	+ 2 6	+ 3 9	+ 3 9	+ 2 6	+ 5 15
1	Bone loss	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	+ 3 3
2	Accuracy required	S 3 6	S 2 4	S 3 6	S 3 6	S 2 4	S + 4 8
	Sum Σ +	4	4	4	4	4	4
	Σ S	5	3	3	3	7	6
	Σ −	2	4	4	4	0	1
	Score	76 61	56 56	61 61	61 61	74 59	71 56
			X				

Group $I_{2\,\text{channel}}$

1	1·2	1·3	2	2·2	2·3
S 1 3	S 1 3	S 1 3	S 1 3	S 1 3	S 1 3
+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15
S 1 3	+ 3 9	+ ~~S~~ 2 6	S 1 3	+ 3 9	− 2 6
+ 5 10	+ 5 10	+ S [illegible] 6	+ 5 10	+ 5 10	+ 3 6
+ 3 6	+ 2 4	+ 3 6	+ 3 6	+ 2 4	+ 3 6
− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0
S 10	S 10	S 10	S 10	S 10	S 10
S 5	S 5	S 5	S 5	S 5	S 5
+ 4 12	S 3 9	+ 4 12	+ 4 12	S 3 9	+ 4 12
S 3 3	S 3 3	S 3 3	S 3 3	S 3 3	S 3 3
+ 4 8	S 3 6	+ 4 8	+ 4 8	S 3 6	+ 4 8
5	4	6	5	4	6
5	6	4	5	6	4
1	1	1	1	1	1
75 60	74 59	74 59	75 60	74 59	74 59

Matrix 3d



Group M_1
Dip

		1	2	3	4	5	6	7
3	Load Transfer	S 2 6	S 2 6	S 2 6	S 2 6	+ 2 6	+ 3 9	+ 3 9
3	Stress conc/ Shielding	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15
3	Stability A-P	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15
2	M-L	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10
2	Axial	– 0 0	S 0 0	+ 3 6	+ 3 6	• – 0 0	+ 3 6	– 0 0
1	Lift-off	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0
2	No Tool change	S 10	S 10	S 10	S 10	S 10	S 10	S 10
1	Large Burr	S 5	S 5	S 5	S 5	S 5	S 5	S 5
3	Simple to cut	+ 4 12	S+ 4 12	+ 4 12	+ 4 12	+ 4 12	S 3 9	+ 4 12
1	Bone Loss	– 1 1	– 1 1	– 1 1	– 1 1	S 3 3	S 2 2	S 1 1
2	Accuracy required	+ 4 8	– 4 8	+S 3 6	+S 3 6	+ 4 8	S 3 6	+ 4 8
	Sum Σ +	5	4	5	5	6	5	6
	Σ S	3	4	54	4	3	5	3
	Σ –	3	3	2	2	2	1	2
	Score	82	82	80	80	84	87	85
		67	67	65	65	69	72	70

Group G_1
curve

		1	2	3	4	5	6	7
3	Load Transfer	+ 3 9	S 2 6	S 1 3	– 0 0	– 0 0	– 0 0	+ 4 12
3	Stress conc/ Shielding	+ 5 15	+ 4 12	+ 4 12	+ 5 15	+ 4 12	+ 4 12	+ 4 12
3	Stability A-P	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0
2	M-L	– 0 0	– 0 0	S 2 4	– 0 0	– 0 0	S 2 4	– 0 0
2	Axial	– 1 2	– 1 2	– 1 2	– 1 2	– 1 2	– 1 2	– 1 2
1	Lift-off	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0	– 0 0
2	No Tool change	S 10	S 10	S 10	S 10	S 10	S 10	S 10
1	Large Burr	S 5	S 5	S 5	S 5	S 5	S 5	S 5
3	Simple to cut	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 5 15
1	Bone Loss	S 2 2	S 2 2	S 2 2	S 2 2	S 2 2	S 2 2	S 3 3
2	Accuracy required	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10	+ 5 10
	Sum Σ +	4	3	43	3	3	43	4
	Σ S	3	4	45	3	3	34	3
	Σ –	4	4	3	5	5	4	4
	Score	68	62	63	59	56	60	69
		53	47	48	44	41	45	54

75

Matrix 3e

Group K_2 slant

		1	1.2	2	3	4
3	Load Transfer	− 0 0	+ 3 9	− 0 0	− 0 0	+ 4 12
3	Stress Conc/ Sheilding	+ 5 15	+ 3 15	S 3 9	S 3 9	+ 4 12
3	Stability A-P	S 3 9	S 3 9	+ 3 9	+ 3 9	S 3 9
2	M-L	S 3 6	S 3 6	S 3 6	S 3 6	+ 4 8
2	Axial	S 3 6	S 3 6	S 3 6	S 3 6	+ 4 8
1	Lift-off	− 0 0	− 0 0	S 2 2	S 2 2	− 0 0
2	No Tool change	S 10	S 10	S 10	S 10	S 10
1	Large Burr	S 5	S 5	S 5	S 5	S 5
3	Simple to Cut	+ 5 15	+ 5 15	S 4 12	S 4 12	+ 5 15
1	Bone Loss	S 4 4	S 4 4	S 4 4	S 4 4	S 4 4
2	Accuracy required	+ 5 10	+ 5 10	S 4 8	S 4 8	+ 4 8
	Sum Σ +	3	4	1	1	6
	Σ S	6	6	9	9	4
	Σ −	2	1	1	1	~~6~~1
	Score	80 65	89 74	71 56	71 56	94 76

Group L_2 line

1	2	3	2.3 $^{2\to}$
S 1 3	S 1 3	S 1 3	+ 3 9
+ 5 15	+ 5 15	+ 5 15	+ 4 12
+ 5 15	+ 5 15	+ 5 15	+ 5 15
S 0 6	− 0 0	− 0 0	− 0 0
+ 4 8	+ 3 6	+ 3 6	+ 3 6
− 0 0	− 0 0	− 0 0	− 0 0
S 10	S 10	− 0	S 10
S 5~~10~~	S 5~~10~~	− 0	S 5
+ 5 15	+ 5 15	+ 5 15	+ 5 15
S 2 2	S 2 2	S 2 2	− 2 2
+ 4 8	+ 4 8	+ 4 8	+ 4 8
5	5	5	6
5	4	2	2
1	2	4	3
[illegible] 81 66	79 64	64 64	82 67

Group Q_3 angle

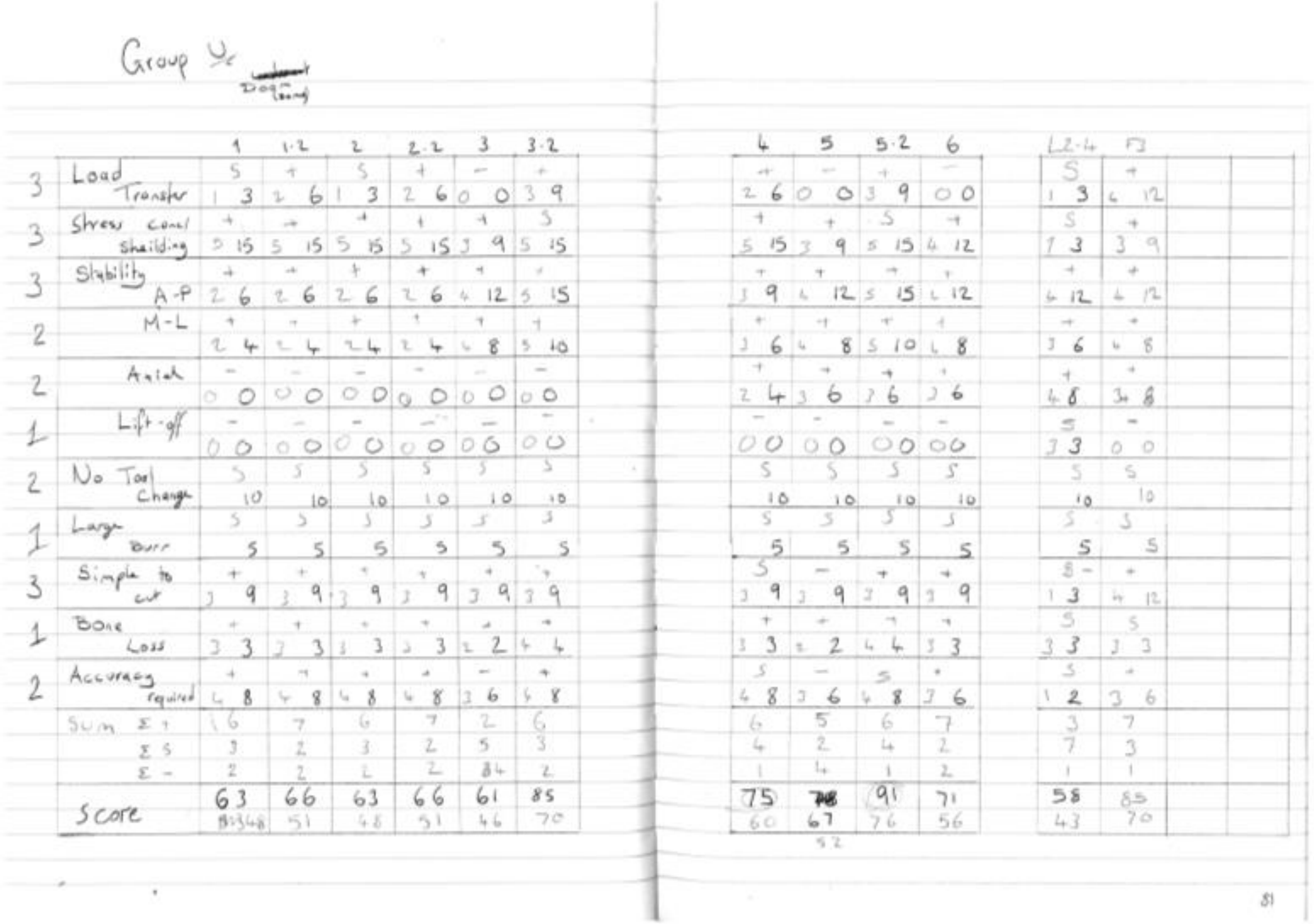
2.3	1	2	3
+ 3 9	S 1 3	S 1 3	S 1 3
+ 4 12	+ 5 15	+ 5 15	+ 5 15
+ 5 15	+ 4 12	+ 4 12	+ 4 12
+ 0 0	+ 4 8	+ 4 8	+ 4 8
+ 3 6	+ 4 8	+ 4 8	+ 4 8
− 0 0	− 0 0	− 0 0	− 0 0
S 10	S 10	S 10	S 10
S 5	S 5	S 5	S 5
+ 5 15	+ 5 15	+ 5 15	+ 5 15
S 2 2	S 2 2	S 2 2	S 2 2
+ 4 8	+ 4 8	+ 4 8	+ 4 8
7	6	6	6
3	4	4	4
1	1	1	1
82 67	86 71	86 71	86 71

Matrix 3f

		Group H				Group A englund		Group W				Group V				Group B	
		1	2	3	4	1	1.2	1	2	3	2.3	1	2	3	2.3	1	1.2
3	Load	+	+	+	+	5	5	5	5	5	+	5	5	5	+	5	+
	Transfer	4 12	4 12	4 12	4 12	1 3	1 3	1 3	1 3	1 3	3 9	1 3	1 3	1 3	3 9	1 3	3 9
3	Stress Conc/	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Sheilding	4 12	4 12	4 12	4 12	2 6	2 6	5 15	5 15	5 15	4 12	5 15	5 15	5 15	4 12	5 15	4 12
3	Stability	+	+	+	+	+	+	+	+	+	+	−	−	−	−	5	5
	A-P	4 12	4 12	4 12	4 12	3 9	3 9	5 15	5 15	5 15	5 15	0 0	0 0	0 0	0 0	4 12	4 12
2	M-L	+	+	+	-	5	5	−	−	−	−	+	+	+	+	5	5
		4 8	4 8	4 8	4 8	3 6	3 6	0 0	0 0	0 0	0 0	5 10	5 10	5 10	5 10	4 8	4 8
2	Axial	-	+	+	+	5	5	+	+	+	+	+	+	+	+	5	5
		4 8	4 8	3 6	3 6	2 4	2 4	3 6	3 6	3 6	3 6	3 6	3 6	3 6	4 8	3 6	3 6
1	Lift-off	-	-	−	−	+ 5	5	-	−	−	−	−	−	−	−	−	−
		0 0	0 0	0 0	0 0	3 3	3 3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2	No Tool	-	5	-	5	−	5	−	5	−	5	-	5	-	5	5	5
	Change	0	10	0	10	0	10	0	10	0	10	0	10	0	10	10	10
1	Large	5	5	5	5	−	5	−	5	−	5	−	5	−	5	5	5
	Burr	5	5	5	5	0	5	0	5	0	5	0	5	0	5	5	5
3	Simple to	5	5	5	5	5	5	+	+	+	+	+	+	+	+	+ 5	+
	cut	4 12	4 12	4 12	4 12	1 3	1 3	4 12	4 12	4 12	4 12	4 12	4 12	4 12	4 12	3 9	3 9
1	Bone	+	+	+	+	5	5	5	5	5	5	5	5	5	5	5	5
	Loss	2 2	2 2	3 3	3 3	3 3	3 3	3 3	3 3	3 3	2 2	3 3	3 3	3 3	2 2	3 3	2 2
2	Accuracy	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	required	3 6	3 6	3 6	3 6	1 2	1 2	4 8	4 8	4 8	4 8	4 8	4 8	4 8	4 8	4 8	4 8
	Sum Σ+	6	6	5	6	2	2	4	4	4	5	4	4	4	5	2	3
	Σ5	3	4	3	4	7	9	3	5	3	4	3	5	3	4	5	7
	Σ−	2	1	2	1	2	0	4	2	4	2	4	2	4	2	1	1
	Score	77	87	78	88	39	54	62	77	62	79	57	72	57	76	79	81
		72	72	73	73	39	39	62	62	62	64	57	57	57	61	64	66

79

Matrix 3g



Group 4c

Dog leg

		1	1.2	2	2.2	3	3.2	4	5	5.2	6	L2-4	F3
3	Load Transfer	S 1 3	+ 2 6	S 1 3	+ 2 6	− 0 0	+ 3 9	+ 2 6	− 0 0	+ 3 9	− 0 0	S 1 3	+ 4 12
3	Stress conc/ Shailding	+ 5 15	+ 5 15	+ 5 15	+ 5 15	+ 3 9	S 5 15	+ 5 15	+ 3 9	S 5 15	+ 4 12	S 1 3	+ 3 9
3	Stability A-P	+ 2 6	+ 2 6	+ 2 6	+ 2 6	+ 4 12	+ 5 15	+ 3 9	+ 4 12	+ 5 15	+ 4 12	+ 4 12	+ 4 12
2	M-L	+ 2 4	+ 2 4	+ 2 4	+ 2 4	+ 4 8	+ 5 10	+ 3 6	+ 4 8	+ 5 10	+ 4 8	+ 3 6	+ 4 8
2	Axial	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	+ 2 4	+ 3 6	+ 3 6	+ 3 6	+ 4 8	+ 34 8
1	Lift-off	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	− 0 0	S 3 3	− 0 0
2	No Tool Change	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10	S 10
1	Large Burr	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5	S 5
3	Simple to cut	+ 3 9	+ 3 9	+ 3 9	+ 3 9	+ 3 9	+ 3 9	S 3 9	− 3 9	+ 3 9	+ 3 9	S − 1 3	+ 4 12
1	Bone Loss	+ 3 3	+ 3 3	+ 3 3	+ 3 3	+ 2 2	+ 4 4	+ 3 3	+ 2 2	+ 4 4	+ 3 3	S 3 3	S 3 3
2	Accuracy required	+ 4 8	+ 4 8	+ 4 8	+ 4 8	− 3 6	+ 4 8	S 4 8	− 3 6	S 4 8	+ 3 6	S 1 2	+ 3 6
	Sum Σ+	16	7	6	7	2	6	6	5	6	7	3	7
	ΣS	3	2	3	2	5	3	4	2	4	2	7	3
	Σ−	2	2	2	2	84	2	1	4	1	2	1	1
	Score	63 81348	66 51	63 48	66 51	61 46	85 70	75 60	78 67	91 76	71 56	58 43	85 70

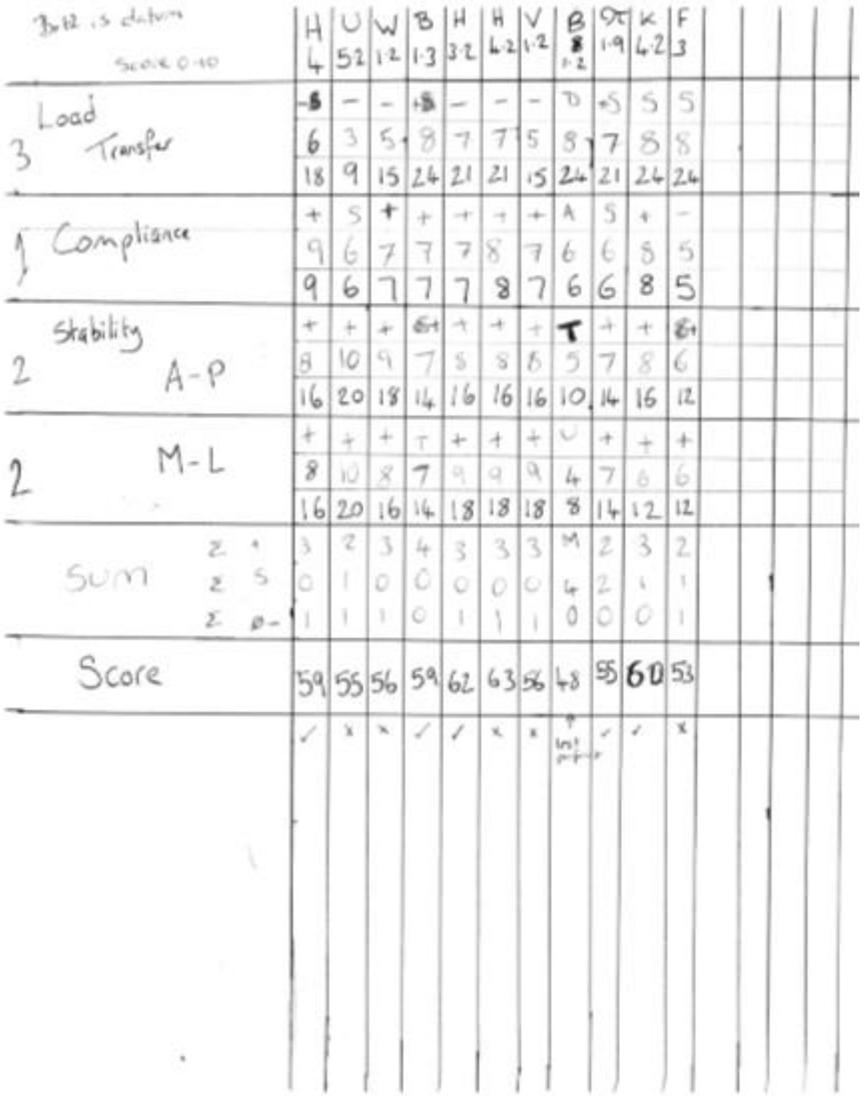
52

81

Matrix 4

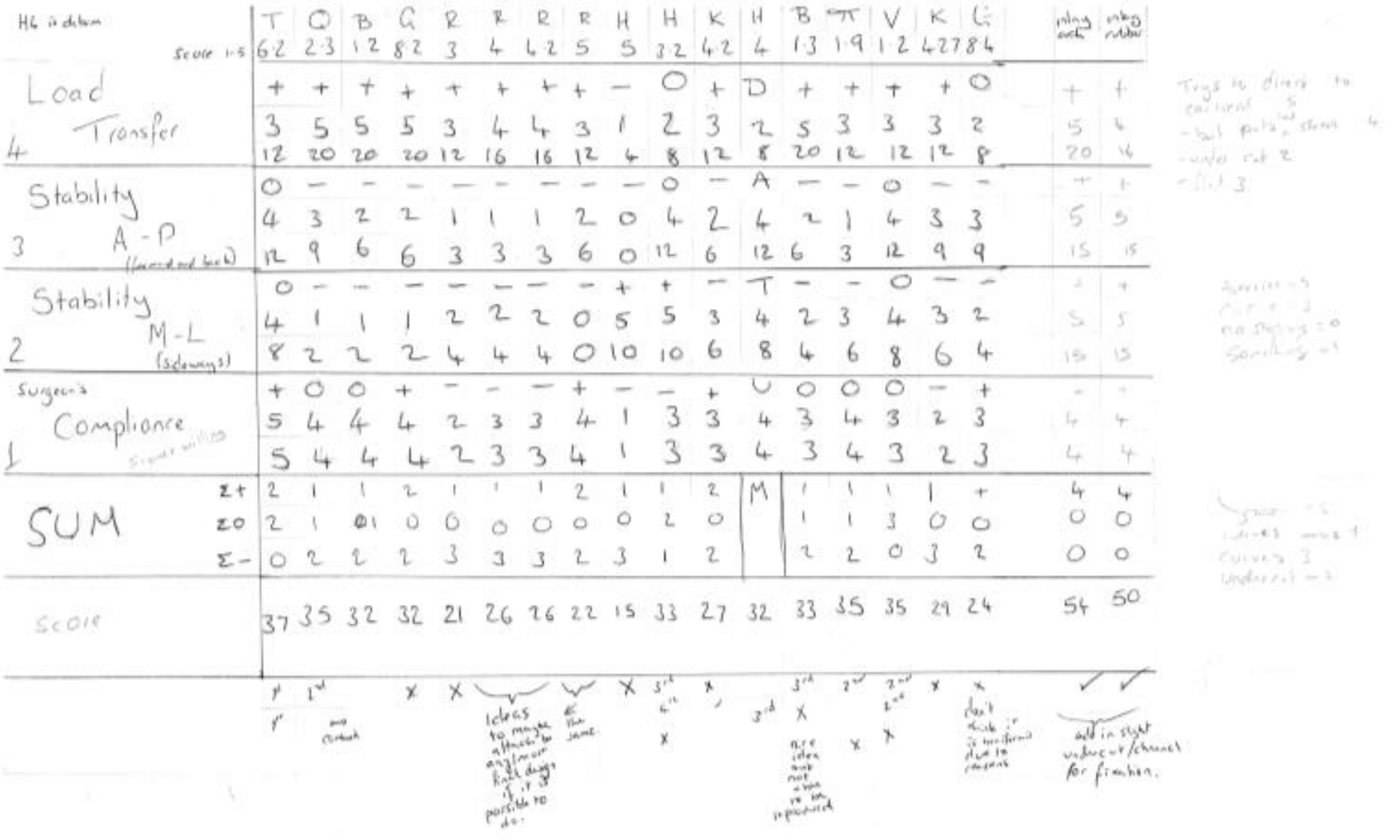
	Standard as datum	[illegible] 1.3	T 6.2	S 2.3	Ċ 5	Ṁ 6	K̇ 4	Q̇ 2.3	Ḣ 4	N 2.3	B̄ 1.2	U 4	Ü 5.2	F̈ 3	W 1.2	Ẅ 1.3	B 1.3	C 5.2	S̈ 3.3	G 8	G 8.2	V 2.3	H 3.2	H 4.2	V 1.2	G 8.2	G 8.3	C 8	[illegible] 1.9	K 4.2
	Load Transfer	+	S	+	S	+	+	-	+	+	-	+	+	-	-	+	+	S	S	+	+	+	+	+	+	-	+	+	+	+
		4	2	5	2	3	4	4	3	4	5	3	3	4	4	5	5	2	2	3	3	3	4	4	4	3	3	4	4	4
3		12	6	15	6	9	12	12	9	12	15	9	9	12	12	15	15	6	6	9	9	9	12	12	12	9	9	12	12	12
	Compliance	+	S	+	S	S	+	+	+	-	+	S	+	-	S	+	+	+	S	+	+	+	+	-	S	+	+	+	S	+
		3	2	4	2	2	3	3	4	3	4	2	3	3	2	4	4	3	2	5	4	4	3	3	2	5	4	3	2	3
1		3	2	4	2	2	3	3	4	3	4	2	3	3	2	4	4	6	2	5	4	3	3	3	2	5	4	3	2	3
	Stability A-P	S	+	-	-	+	+	+	+	+	+	S	+	+	+	+	+	+	S+	+	-	-	+	-	+	S	S+	+	+	+
		3	4	2	4	4	4	4	5	4	4	3	5	3	5	4	4	4	4	0	0	0	5	5	5	3	4	3	5	4
2	(forward-back)	6	8	4	8	8	4	4	10	8	8	6	10	6	10	8	8	8	8	0	0	0	10	10	10	6	8	6	10	8
	M-L	S	+	-	+	+	S	S	+	-	+	S	+	+	+	+-	+	+	+	-	S	S	-	+	+	S	S	S	+	+
2		3	4	2	4	4	3	3	4	0	4	3	5	3	4	2	3	4	4	0	3	3	4	4	5	3	3	2	5	4
	(Sideways)	6	8	4	8	8	6	6	8	0	8	6	10	6	8	4	6	8	8	0	6	6	8	8	10	6	6	4	10	8
	Sum Σ+	2	2	2	2	3	3	3	4	3	4	1	4	4	3	3	4	3	1	2	2	2	4	4	3	2	3	3	3	4
	ΣS	2	2	0	2	1	1	1	0	0	0	3	0	0	1	0	0	1	3	0	1	1	0	0	1	2	1	1	1	0
	Σ-	0	0	2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	1	1	0	0	0	0	0	0	0	0
	Score	27	24	27	24	27	25	25	31	23	27	23	32	27	32	23	33	26	24	14	19	18	33	33	34	26	27	25	34	31
		→		→ S 3.3	→ C 5.2	→	→ K 4.2			→						→ G 8.3				→ improved G 8.2	→ G 8.3									
								3	✓ 4	3	✓ 4	1	✓ 4	✓ 4	✓ 3	3	✓ 4	3	X 1	2	2	2	✓ 4	✓ 4	✓ 3	2	3	1	✓ 3	✓ 4

Matrix 5



B1·2 is datum Score 0-10	H 4	U 52	W 1·2	B 1·3	H 3·2	H 4·2	V 1·2	B 8 1·2	9π 1·9	K 4·2	F 3
3 Load Transfer	-S	–	–	+S	–	–	–	D	+S	S	S
	6	3	5	8	7	7	5	8	7	8	8
	18	9	15	24	21	21	15	24	21	24	24
1 Compliance	+	S	+	+	+	+	+	A	S	+	–
	9	6	7	7	7	8	7	6	6	8	5
	9	6	7	7	7	8	7	6	6	8	5
2 Stability A-P	+	+	+	S+	+	+	+	T	+	+	S+
	8	10	9	7	8	8	8	5	7	8	6
	16	20	18	14	16	16	16	10	14	16	12
2 M-L	+	+	+	T	+	+	+	U	+	+	+
	8	10	8	7	9	9	9	4	7	6	6
	16	20	16	14	18	18	18	8	14	12	12
Sum Σ +	3	2	3	4	3	3	3	M	2	3	2
Σ S	0	1	0	0	0	0	0	4	2	1	1
Σ 0 -	1	1	1	0	1	1	1	0	0	0	1
Score	59	55	56	59	62	63	56	48	55	60	53
	✓	x	x	✓	✓	x	x	? Int [illegible]	✓	✓	x

Matrix 6



H6 is datum	T	Q	B	G	R	R	R	R	H	H	K	H	B	π	V	K	G	inlay arch	inlay rubber
Score 1-5	6.2	2.3	1.2	8.2	3	4	4.2	5	5	3.2	4.2	4	1.3	1.9	1.2	4.2	7.8 4		
Load Transfer	+	+	+	+	+	+	+	+	−	O	+	D	+	+	+	+	O	+	+
	3	5	5	5	3	4	4	3	1	2	3	2	5	3	3	3	2	5	4
4	12	20	20	20	12	16	16	12	4	8	12	8	20	12	12	12	8	20	16
Stability A-P (forward and back)	O	−	−	−	−	−	−	−	−	O	−	A	−	−	O	−	−	+	+
	4	3	2	2	1	1	1	2	0	4	2	4	2	1	4	3	3	5	5
3	12	9	6	6	3	3	3	6	0	12	6	12	6	3	12	9	9	15	15
Stability M-L (sideways)	O	−	−	−	−	−	−	−	+	+	−	T	−	−	O	−	−	+	+
	4	1	1	1	2	2	2	0	5	5	3	4	2	3	4	3	2	5	5
2	8	2	2	2	4	4	4	0	10	10	6	8	4	6	8	6	4	15	15
Surgeon's Compliance (surgeon willing)	+	O	O	+	−	−	−	+	−	−	+	U	O	O	O	−	+	+	+
	5	4	4	4	2	3	3	4	1	3	3	4	3	4	3	2	3	4	4
1	5	4	4	4	2	3	3	4	1	3	3	4	3	4	3	2	3	4	4
SUM Σ+	2	1	1	2	1	1	1	2	1	1	2	M	1	1	1	1	+	4	4
Σ0	2	1	~~0~~1	0	0	0	0	0	0	2	0		1	1	3	0	0	0	0
Σ−	0	2	2	2	3	3	3	2	3	1	2		2	2	0	3	2	0	0
Score	37	35	32	32	21	26	26	22	15	33	27	32	33	35	35	29	24	54	50
	1st 1st	1st no contact		x	X	ideas to maybe attach to any/more knit designs if it is possible to do.		≡ the same	X	3rd 4th X	x	3rd	3rd X are idea and not able to be reproduced	2nd X	2nd 2nd X	x	x don't think it is uniform due to reasons	✓ add in slight undercut/channel for friction.	✓

Trys to direct to cortical 5
- but puts [illegible] down 4
- under cut 2
- flat 3

Anterior +5
Curve +3
no sloping = 0
Sometimes +1

Sprue [illegible]
curves [illegible]
Curves 3
Undercut −1