ENGINEERING

McMaster University

Project 2 – Independent Research Summary

Total Knee Replacement

ENGINEER 1P13 – Integrated Cornerstone Design Projects

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Executive Summary

A total knee replacement is a device that replaces the entire knee joint and emulates its functions. One type of total knee replacements (TKR) is semi-constrained TKR, it limits the rotation and movement in certain planes hence its name. There is no link across the joints of the knee. Common devices utilized are metal femoral component and polymer tibial/patellar components. Common materials utilized within TKR's are Cobalt-chromium alloys, Polymethyl Methacrylate, Titanium, Titanium alloys, and Ultra-High Molecular Weight Polyethylene. Overall, the device can provide durable, long-lasting, and high-mobility knee functionality utilizing materials which already mimic knee tissue.

Annotated Bibliography

[1] N. Shayesteh Moghaddam et al., "Metals for bone implants: safety, design, and efficacy," Biomanufacturing Reviews, vol. 1, no. 1, pp. 1–16, Dec. 2016, doi: 10.1007/s40898-016-0001-2.

This article discusses the use of titanium, variations of nickel-titanium, and magnesium for metal implants. Nickel-titanium improves upon titanium as its able to be grafted onto bones better than titanium because of its porous nature. The importance of porous compounds in bone implants is due to how well the material can attach itself to the bone and avoid aseptic loosening over a given period which titanium has been shown to do. Porous nickel titanium is also capable of allowing bone tissue to regrow even under stress due to a study on implanting nickel-titanium in rabbits. Nickel-titanium is also less toxic and is biocompatible which able to provide cell regrowth at the cost of a higher chance of infection. The article then discusses the possibilities of nickel-titanium being utilized in future implants and the certain possible treatments nickel-titanium can undergo to increase its usability.

[2] "Mobile Bearing Total Knee Replacement Devices," *ASTM Special Technical Publication*, vol. 1531 STP. ASTM International, 2012, doi: 10.1520/stp1531-eb.

This article discusses the design, points of failure, and components of the mobile bearing total knee replacements (MBTKR). Specific parts such as the baseplate, the tibial bearings, and rotational stops. The baseplate had issues regarding the plastic material utilized which would exhibit flaking throughout multiple years of wear causing a buildup of plastic debris stunting the range of motion of the knee prosthesis. The tibial baseplate experienced deformation under high amounts of torsion which would slowly deform the overall MBTKR overtime and the overall "Spin-out and Spit-out" design had major issues if the MBTKR experienced rapid changes in motion which would damage the bearing restraints. The article mentions better testing methods for future MBTKR designs that can provide long term statistics.

[3] *Total knee replacement: an evidence-based analysis*. Medical Advisory Secretariat, 2005.

This article analyzes total knee replacements (TKR) in Ontario and goes in depth into the design, statistics, and outcomes of TKR surgeries. The article states that many types of total

knee replacement (TKR) such as semi-constrained, non-constrained, and constrained TKR and their benefits and uses. Semi-constrained TKR's provides its own stability without relying heavily on the patient's muscles. Non-constrained TKR's don't have any linked artificial components. As well as the design fully relies on the patient's muscles and ligaments for stability. Within the constrained TKR's, the components of the artificial knee are linked together and can stabilize itself. These TKR are not as long lasting as other types of TKR's. The article then analyzes the risks, complications of knee replacements and effectiveness of the procedure.

Additional References

[1] M. Elahinia *et al.*, "Additive manufacturing of NiTiHf high temperature shape memory alloy," *Scripta Materialia*, vol. 145, pp. 90–94, Mar. 2018, doi: 10.1016/j.scriptamat.2017.10.016.

[2] R. B. Bourne, B. M. Chesworth, A. M. Davis, N. N. Mahomed, and K. D. J. Charron, "Patient satisfaction after total knee arthroplasty: Who is satisfied and who is not?," in *Clinical Orthopaedics and Related Research*, Oct. 2010, vol. 468, no. 1, pp. 57–63, doi: 10.1007/s11999-009-1119-9.

[3] M. Levine, K. McElroy, V. Stakich, and J. Cicco, "Comparing conventional physical therapy rehabilitation with neuromuscular electrical stimulation after TKA," *Orthopedics*, vol. 36, no. 3, pp. e319–e324, Mar. 2013, doi: 10.3928/01477447-20130222-20.

[4] Ansys Granta EduPack software, Granta Design Limited, Cambridge, UK, 2020 (www.grantadesign.com)