An Early Stage Assessment of Cost Savings from the use of Ossis Custom Trabecular Acetabular Revision Components in the Treatment of Severe Acetabular Defects

D. Body, BE. MBA., M. Martin, B.Com. BE. MEngSt., J. Hands, LLB. BCom
Ossis Limited, Christchurch, New Zealand

Abstract

While there have been many studies that explore the efficacy of prostheses used in acetabular revision arthroplasties, limited research has been done into the economic value that flows from the use of different prostheses. As the population continues to age and healthcare costs rise, it may no longer be sufficient for prostheses to simply deliver superior clinical outcomes. The economic cost of those outcomes and their relativity will assume greater importance. The study summarised in this paper is an early stage assessment of cost savings resulting from the use of Ossis' custom trabecular acetabular revision component in comparison to the use of tantalum shell and augment systems. Through discussions with industry and analysis of data provided by both public and private sector healthcare funders and providers, the authors have determined that on average the treatment of severe acetabular defects, in the public healthcare system, using an Ossis custom trabecular acetabular component results in a total cost saving of approximately $5,309 in comparison to the use of tantalum systems. This cost saving stems mainly from improved bed and theatre utilisation and reduced risk of prosthesis failure and complications. The total cost saving represents a 14.3% saving on the estimated current total cost of treating severe acetabular defects using tantalum systems. The magnitude of the cost saving may also mean that the Ossis component is an economically viable option for the treatment of less severe acetabular defects (for example Paprosky 2c defects).

Introduction

Over the last decade there has been a growing interest by orthopaedic clinicians in the use of custom implants in joint replacement, as imaging, computing and additive manufacturing technologies have developed and converged.[1]

The use of these technologies is especially relevant to the treatment of severe joint defects, for example acetabular defects, where the native bone has diminished to the point where it is not possible to use an "off the shelf" implant. These types of defects are classed as Paprosky 3a and 3b type defects.[2] Additionally the treatment of pelvic tumours and discontinuities may also benefit from the use of custom implants.

Approximately 7,500 hip replacement procedures (arthroplasties) are performed annually in New Zealand.[3] Of this total number approximately 1,150[4] are revision arthroplasties and of this number we believe that approximately 160 are classified as Paprosky type 3a and 3b. Added to this are pelvic tumours and discontinuities.

In New Zealand revision arthroplasty procedures are undertaken in both the private and public hospital systems, with approximately 67% being performed in public hospitals.[5] With regard to complex acetabular revision procedures however, we believe that the proportion performed in public hospitals may be as high as 90% - 95%.[6] Therefore surgeons working in public hospitals represent the primary target customer group for any orthopaedic company seeking to sell orthopaedic implants designed to address complex acetabular defects.

Currently there are only a small number of prostheses available on the New Zealand market to treat severe acetabular defects. These are typically "off the shelf" modular porous implants, such as tantalum shell and augment systems ("TM systems"). While "off the shelf" implants are commonly used, they suffer in that they do not take into account the specific anatomy and physiology of the patient in question or the specific nature of the defect being addressed.

Custom implants however are recognised for their ability to address patient specific defects,[7] increased accuracy of hip centre positioning and their encouragement of osseo-integration helping to avoid costly complications which can extend surgical and rehabilitation times or result in a hastened need for re-revision.

The objective of this study is to benchmark the cost of treating severe acetabular defects using an Ossis

1. Tredinnick et al. (2013)
2. Paprosky et al. (1994)
3. New Zealand Joint Registry (2013), 15
4. Ibid, 20
5. Correspondence with administrator at New Zealand Joint Registry, 22 January, 2014
6. Interview with private hospital administrator, 15 January, 2014 and review of Ossis records
7. Taylor et al. (2013)

custom component, against the cost of using TM systems, in the New Zealand public healthcare system.

Future studies may consider benefits to private hospital operators and private healthcare funders. We have however included in this paper information from private hospital operators, where that information brings context to information from the public system.

Government Funding of Public Healthcare in New Zealand

There are 20 District Health Board's (DHB's) in New Zealand. They were established in 2001 under the New Zealand Public Health and Disability Act 2000. DHB's are responsible to the Minister of Health for providing, or funding the provision of health and disability services in their districts. Funding of DHB's is allocated via a population/demographic-based formula by the Ministry of Health (MoH) as part of formal crown funding agreements between the MoH and DHB's.

Given that crown funding agreements do not explicitly take into account specific cases it is very unlikely that overall funding to DHB's will be reduced to reflect cost savings resulting from the use of Ossis' component. We therefore believe that in the long term any savings in the cost of treating severe acetabular defects will remain with the DHB's and not be passed onto the MoH.

Ossis Custom Trabecular Acetabular Revision Component

Presently Ossis' key product offering is its custom trabecular acetabular revision component, refer figure 1.

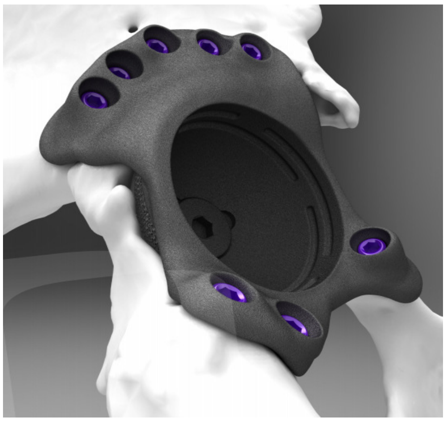

Figure 1: Ossis Custom Trabecular Acetabular Revision Component

The Ossis component is currently sold in both the Australian and New Zealand markets at a price of A/NZ$18,000 (excl. gst).

The design process for the Ossis component entails Ossis' orthopaedic engineers working with surgeons to produce specialised components that address the specific needs of the individual patient. In most cases Ossis' components are used to address defects of a severity that limit the effective use of "off the shelf" implants to achieve desired results. Presently Ossis' components are targeted at cases where defects are of Paprosky 3a classification and worse.

A standardised design process is followed for each case that ensures that the implant meets the surgeon's needs. This process involves the development of 3D rendered designs of the component for approval by the surgeon, creation of trial models for use by the surgeon and consultation with the surgeon. In essence Ossis' custom implants are specifically designed to fit the bone, rather than making the bone fit the implant as is the case with TM systems, allowing the patient's specific defect to be more effectively treated.

Drivers of Cost Savings from the use of Ossis' Custom Trabecular Acetabular Revision Component

There are a number of identifiable factors that contribute to the total cost of treating complex acetabular defects and hence cost savings derived from the use of an Ossis component instead of a TM system. These factors include:[8,9]

- hospital theatre and bed utilisation;
- clinician productivity;
- prosthesis costs; and
- rehabilitation and long-term care costs[10,11]

Many factors impact upon these costs, for example the patient's age, the nature of the surgery (full revision, single component or liner change), the number of previous revisions the patient has received, the extent of bone damage and if the patient suffers from any compounding medical conditions. [12]

Revision acetabular arthroplasty also has a number of potential future costs associated with it. Potential future costs are mainly linked to the risk of further revisions being required in the future due to the failure of the previous revision procedure or complications. These future costs are associated with implant or surgical failure. As such, by selecting the most appropriate implant it may be possible to minimise both immediate costs and potential future costs.[13]

8. Burns et al. (2010)
9. Gaver et al. (2010)
10. Interview with physiotherapist, 7 December, 2013
11. Burns, 205
12. Interview with surgeon, 10 December, 2013
13. Gillespie et al. (1995)

Hospital Bed Utilisation

Patient length of hospital stay is recognised as a significant contributor to the total cost of revision arthroplasty.[14]

Information from private and public healthcare providers suggests that the cost of a hospital bed is approximately $1,200 per day.[6,15] This estimate is validated by a 2012 study by the International Federation of Health Plans which indicated that the average daily bed cost in New Zealand was US$979.[16]

The MoH has advised the authors that the average patient stay following revision hip arthroplasty is 8 days.[17] DHB data indicates that the average length of patient stay following a complex hip revision arthroplasty is in the range of 7 - 10 days (average 8.5 days) and can extend to up to 20 days[18] if the patient is non-weight bearing and requires long term care where they are in bed to chair status only.[19,20] Given the nature of severe acetabular defects it is likely that length of stay associated with revisions of these types (presumably using TM systems) will ordinarily be at the upper end of the 7 – 10 day range.

Ossis' experience is that its patients are weight bearing to the point that they can be discharged by days 4 or 5 post-surgery suggesting a significant saving from the use of an Ossis component for complex hip revision arthroplasty.[21-23] Further the authors have been advised that it is possible save a minimum of at least 4 days in the public healthcare system through the use of an Ossis component and depending on patient characteristics up to 14 days.[24]

On the basis of the information outlined in this section, the current average total cost of stay in the public healthcare system, following a complex hip revision arthroplasty using a TM system, is estimated to be $10,200 (average of 8.5 days at $1,200 per day), whereas the estimated cost of stay following an arthroplasty using an Ossis component is $5,400, (4.5 days at $1,200 per day), resulting in a saving of $4,800 from the use of an Ossis component.

Hospital Theatre Utilisation

Analysis of information provided by major DHB's and a private hospital operator suggests that the average operating theatre variable cost is $1,200 an hour.[6,25-27] This cost includes all theatre staff, anaesthetic costs, equipment, recovery, facility costs and overheads. It assumes 3 nursing staff and an assistant as per anecdotal evidence.[28] However it excludes anaesthetist and surgeon costs, which we analyse separately.

In terms of theatre time required to perform a revision arthroplasty we were advised by a major DHB that the average time for a revision hip arthroplasty is 244 minutes (4.1 hours) and that the maximum theatre time was 500 minutes (8.3 hours).[29] Information from other DHB's indicates that the average procedure time for a complex acetabular revision using an "off the shelf" component lies in the range of 3.6 – 4.1 hours ($4,320 - $4,920),[30,31] whereas clinicians have advised the authors that the average procedure time for a complex acetabular revision using an Ossis component is in the range of 2.5 – 3 hours ($3,000 - $3,600).[32,33]

Actual theatre time taken to complete a specific arthroplasty may however be more or less than these averages given:

1. The extent of surgery required, for example is the revision an arthroplasty where all components are replaced (both the acetabular and femoral components) or are only some components being replaced? An arthroplasty is likely to take longer than average if all components are being replaced meaning the theatre cost will be proportionally greater;
2. The complexity of the surgery required to treat severe acetabular defects is significantly more challenging than that for an "average" revision surgery. As such it is again likely that a procedure of this type would take significantly longer than an "average" revision; and
3. The characteristics of the patient. For instance a procedure on an older, overweight patient who is suffering other medical conditions is likely to be more complex than from a fit and healthy young patient where for example there is less work required to access the joint.

Based on the information summarised in this section the authors believe that the use of an Ossis component in the treatment of severe acetabular defects will, at a minimum, reduce theatre time by 1.1 hours (or $1,320 at a theatre operating cost of $1,200 per hour).[34]

14. Robinson et al. (2012)
15. Interview with physiotherapist, 7 December, 2013
16. International Federation of Health Plans (2014)
17. Ministry of Health (2014)
18. Auckland DHB (2014)
19. Interview with physiotherapist, 7 December, 2013
20. Interview with hospital administrator, 7 January, 2014
21. Email correspondence with surgeon, 13 January, 2014
22. Interview with surgeon, 17 January, 2014
23. Interview with physiotherapist, 7 December, 2013
24. Interview with surgeon, 17 January, 2014
25. Bay of Plenty DHB (2013)
26. Lakes District DHB (2014)
27. Auckland DHB, OIA
28. Interview with healthcare professional, 12 December, 2013
29. Auckland DHB, OIA
30. Bay of Plenty DHB, OIA
31. Auckland DHB, OIA
32. Interview with surgeon, 17 January, 2014
33. Email correspondence with surgeon, 13 January, 2014
34. Interview with surgeon, 17 January, 2014

Clinician Productivity

In New Zealand, orthopaedic surgeons working in public hospitals are typically contracted on the basis of fixed remuneration for an agreed number of hours per week. A small number of DHB's (for example Canterbury and Waitemata) contract with some surgeons on a limited "fee for service" model, where an agreed fee is paid per procedure.

This study only considers the fixed remuneration model as it is by far the most common remuneration model in the New Zealand public healthcare system.

We have been advised that the average annual remuneration of an experienced orthopaedic surgeon in the public healthcare system is around $230,000. This equates to approximately $190 per hour after holidays, Kiwisaver, continuing education, allowances and the like are considered. We assume that anaesthetists are on a similar effective rate.

Total clinical time required for each case from the surgeon will substantially exceed the average surgical time (4.1 hours) as the surgeon is required to undertake pre and post-surgical consultations, surgical planning and writeups. We estimate surgeon and anaesthetist input of 10 hours ($1,900) and 5.5 hours ($1,045) respectively into a complex acetabular revision using a TM system.

As previously identified in the section considering theatre costs the use of an Ossis custom acetabular component is expected to reduce theatre time by approximately 1.1 hours, compared to the use of a TM system.

We therefore estimate that clinician cost savings to DHB's, due to faster procedure times for the Ossis component in comparison to TM systems, may be approximately $209 per procedure, for each of the surgeon and the anaesthetist.

We note however that the 1.1 hours saving in theatre time for the surgeon may be offset to some degree by time that the surgeon contributes to designing and signing off the Ossis component, which in itself could be mitigated through faster rehabilitation times associated with the Ossis component.

Prosthesis Cost

The prosthesis is typically the largest single contributor to the total cost of revision hip arthroplasty. On a comparative basis the total cost of a commonly used TM system is $14,500[35] (excl. gst) and the Ossis component is $18,720 (excl gst) ($18,000 for the component and $720 for the screws), the difference in cost being $4,220 in favour of the cost of TM systems. It should be noted however that this analysis relates to a TM system configured for a Paprosky 3b defect. The cost of a TM system to treat a pelvic discontinuity may be substantially more than this.

Rehabilitation Costs

We have been advised that most patients in the public system will receive out-patient rehabilitation and that it may be possible to save costs on rehabilitation if a prosthesis can achieve superior weight-bearing results for the patient and earlier stability.[36,37]

In many hospitals, in-patient rehabilitation is worked into bed costing.[38] Therefore in this analysis we only consider the cost of out-patient rehabilitation. According to information provide by a DHB across 69 revision surgeries performed by that DHB in 2012 an average of approximately $21 was spent on out-patient physiotherapy and $2,350 on care in the home.[39] Therefore the average cost for out-patient rehabilitation was $2,371.

The largest area in which cost savings can be made would be in the area of home care due to a decreased need for this service when patients are able to fully weight bear upon discharge. Given the observed early weight-bearing results for patients who have received an Ossis component the authors have adopted an average 33% reduction in the cost of out-patient rehabilitation, being $782.

Actual savings in rehabilitation costs may however be significantly understated by this analysis as a number of studies[42,52-54] noted that 3 – 6 months post-operative care was required by patients receiving a TM system. Care included being fitted with an abduction brace or assisted movement using a "Zimmer" type frame, with touch weight bearing only during that time. Care at this level, for such a long period, is likely to be significantly more expensive than average.

Value of Failure and Complication Risks

Revision hip arthroplasty is associated with significant failure and complications rates. Failure may require the replacement of the revision prosthesis or a component of the prosthesis or surgical intervention for infection or dislocation, any of which would present a healthcare providers with a significant (and unfunded) financial liability.

35. Price list of an OEM supplying TM systems

36. Interview with surgeon, 17 January, 2014
37. Interview with physiotherapist, 7 December, 2013
38. Interview with physiotherapist, 7 December, 2013
39. Auckland DHB, (2014)

We reviewed 17 peer-reviewed studies[40-56] on the performance of TM systems (n=643, average follow-up of 3.9 years) used in procedures involving severe acetabular defects and pelvic discontinuities. We determined that the average failure rate across these studies was 7.8%. Failure was taken as re-revision, partial replacement and further surgical intervention (for example the treatment of deep infections or open reductions of dislocations). When considering the cost of failure of TM systems it should be noted that:

1. Survivorship data for the TM system is of relatively short duration. Survivorship may decrease in the longer term. Our analysis of the study data indicates that the annual failure rate (average failure rate divided by average FU) does not materially change as the average FU increases, which implies total failures continue to increase over time;
2. A number of studies mentioned that the use of TM systems may not be suitable for treating discontinuities which could lead to higher than the average failure rates when treating very severe defects.[40,57]

We estimate that the average total cost (in the public system) of treating a failure is approximately $25,550. Therefore based on a 7.8% failure rate the value of failure risk for TM systems is $1,993 ($25,550 x 7.8%) per case.

A number of the studies mentioned that the use of TM systems also carries a high complication rate.[44,55,58] Our analysis of complication data indicates that the average (non-surgical) complication rate was 8.0%. Non-surgical complications include infections, dislocations and instability.

We estimate that the average total cost (in the public system) of treating a non-surgical complication is approximately $2,700. Therefore based on an 8% complication rate the value of complication risk is $216 ($2,700 x 8%) per case.

40. Abolghasemian et al. (2013)
41. Ballester et al. (2010)
42. Borland et al. (2012)
43. Davies et al. (2011)
44. Del Gaizo et al. (2012)
45. Elanzoury et al (2013)
46. Flecher et al. (2008)
47. Flecher et al. (2010)
48. Lingaraj et al. (2009)
49. Nehme et al. (2004)
50. Schwarzkopf et al. (2014)
51. Siegmeth et al. (2009)
52. Sporer et al. (2006)
53. Sporer et al. (2006)
54. Sporer et al. (2012)
55. Van Kleunen et al. (2009)
56. Weeden et al. (2007)
57. Blumenfeld et al. (2014)
58. Paprosky, (2012)

The total value of the combined failure and complications risks is therefore estimated to be $2,209 per case.

The value of the failure/complication risk identified in this section may substantially underestimate the actual value of the risk as each re-revision gets progressively harder due to diminishing bone stock and the risk of infection, resulting in progressively longer procedure times, lengths of stay and rehabilitation needs.

Due to superior placement, fixation, design and support, the Ossis component has yet to have experienced a component related failure and therefore no recipient has undergone re-revision with the Ossis component to date. Further it has been communicated by industry participants that in their opinion there is no reason for a patient receiving an Ossis component to require re-revision surgery for any reason associated with the prosthesis.[59-62] To date only one non-surgical infection has reportedly been associated with an arthroplasty using an Ossis component, although that infection was present prior to surgery and was not attributable to the use of the Ossis component. Accordingly we do not attribute any value to complication risk associated with the use of Ossis components to date.

Accepting these results implies that use of an Ossis component in revision acetabular surgery removes all potential financial liability associated with failure and complication risk.

Economics of the use of an Ossis Custom Trabecular Acetabular Revision Component in Complex Hip Revision Arthroplasty

Our analysis indicates that the current total cost of a complex acetabular revision using TM systems is estimated to be approximately $37,145 (including the value of failure and complication risks). Refer Appendix 1.

With reference to Table 1, the net cost saving from the use of an Ossis component is estimated to be $5,309 (14.3% of total cost) and are allocated to each cost driver as shown. Clearly savings stemming from improved bed and theatre utilisation and the mitigation of failure and complication risk represent the majority of the gross cost saving and more than offset the higher cost of the Ossis component in comparison to the TM system.

59. Interview with physiotherapist, 7 December, 2013
60. Interview with surgeon, 17 January, 2014
61. Email correspondence with surgeon, 13 January, 2014
62. Interview with healthcare professional, 12 December, 2013

Table 1: Summary of the Cost Savings from the Use of an Ossis Component – Public Healthcare System (excl. gst)

	Cost Saving	%
Bed Utilisation	$4,800	50.4%
Failure/Complication Risk	$2,209	23.2%
Theatre Utilisation	$1,320	13.9%
Rehabilitation	$782	8.2%
Clinicians	$418	4.4%
Gross Cost Saving	**$9,529**	**100.0%**
Prosthesis	($4,220)	
Net Cost Saving	**$5,309**	

The benefits that flow to DHB's from the use of the Ossis component are largely in the form of improved utilisation of theatres and ward beds, greater clinician productivity and the mitigation of failure and complication risk.

With respect to theatre utilisation for example the New Zealand Hip Registry indicates that the mean time to complete a primary hip is 80 minutes (1.3 hours),[63] which is approximately the time saved in a complex acetabular revision through the use of an Ossis component (1.1 hours).

The magnitude of the resulting net cost saving may also mean that the Ossis component is also an economically viable option for the treatment of less severe acetabular defects (for example Paprosky 2c defects).

Conclusions

With respect to the use of Ossis custom trabecular acetabular revision components in the treatment of severe acetabular defects in the public healthcare system, we conclude from this study that:

1. The additional cost of the Ossis component over that of TM systems is significantly less than the gross cost saving, resulting in a net cost saving to DHB's of $5,309 per case, from the use of the Ossis component;
2. The net cost saving to DHB's from the use of an Ossis component is approximately 14.3% of the current total cost of a complex acetabular revision procedure using a TM system;
3. The DHB's capture the cost saving through improved asset utilisation (theatres and beds), increased clinician productivity and the mitigation of failure and complication risk; and
4. The collection of further high quality data on the use of both the Ossis component and the TM system in the treatment of severe acetabular defects should be considered a priority; and
5. The magnitude of the resulting net cost saving may also mean that the Ossis component is also an economically viable option for the treatment of less severe acetabular defects (for example Paprosky 2c defects), but further analysis is required to determine this.

Authors Note

The authors acknowledge that this study relies in part on anecdotal comments and information, while collected in a rigorous fashion, may not specifically relate to complex revision hip arthroplasty (for example some DHB data simply relates to revision hip arthroplasties ranging from straight forward to complex).

Wherever possible we have sought independent validation of those anecdotal comments and our interpretation of "average" data.

References

Abolghasemian M, Tangsataporn S, Sternheim A, Backstein D, Safir O, Gross AE. Combined trabecular metal acetabular shell and augment for acetabular revision with substantial bone loss: a mid-term review. *Bone Joint J*. 2013 Feb; 95-B(2):166-72

Auckland DHB. *"Hip Revision Information."* (Official Information Request, released January 15, 2014). https://www.fyi.org.nz/request/1346/response/5250/attach/3/SC454E0100314011715490.pdf

Bay of Plenty DHB. *"Hip Revision Information."* (Official Information Request, released December 19, 2013). https://www.fyi.org.nz/request/1345-information-on-hip-revision-surgeries#incoming-5183

Ballester Alfaro J, Sueiro Fernandez J. Trabecular Metal Buttress augment and the Trabecular Metal cup-cage construct in revision hip arthroplasty for severe acetabular bone loss and pelvic discontinuity. *Hip International* 2010;20 Supp 7:S119-27

Beckman, Nicholas, Weiss, Stefan, Klotz, Matthias, Gondan, Matthias, Jaeger, Sebastian and Bitsch, Rudi . Loosening After Acetabular Revision: Comparison of Trabecular Metal and Reinforcement Rings. A systematic review. *J Arthroplasty* 29 (2014):229-235

Blumenfeld T, Meehan J. The Use of Augment Devices in Revision Acetabular Surgery. *JBJS Reviews* 2014;2(3):e4

Borland WS, Bhattacharya R, Holland JP, Brewster NT. Use of porous trabecular metal augments with impaction bone grafting in management of acetabular bone loss. *Acta Orthop*. 2012 Aug;83(4):347-52. Epub 2012 Aug 20

Bozic, K. J., Cisternas, M., Katz, P., Ries, L., and Showstack, J. Hospital resource utilization for primary and revision total hip arthroplasty. *J. Bone Joint Surg. Am.* 87(2005):570-576

Burns, Alexander and Bourne, Robert. Economics of revision total hip arthroplasty. *Current Orthopaedics* 20 (2006):203-207

63. New Zealand Joint Registry (2013), 17

Colen, Sascha, Harake, Ramzi, De Haan, Julien and Mulier, Micheal. A modified custom-made triflanged acetabular reconstruction ring (MCTARR) for revision hip arthroplasty with severe acetabular defects. *Acta Orthop. Belg.,* 79 (2013):71

Davies JH, Laflamme GY, Delisle J, et al. Trabecular metal used for major bone loss in acetabular hip revision. *J Arthroplasty* 2011;26–8:1245

Del Gaizo DJ, Kancherla V, Sporer SM, et al. Tantalum augments for Paprosky IIIA defects remain stable at midterm followup. *Clin Orthop Relat Res* 2012;470–2:395

Elganzoury I, Bassiony A A. Early results of Trabecular Metal augment for acetabular reconstruction in revision hip arthroplasty. *Acta Orthop. Belg*., 2013, 79, 530-535

Health Funds Association of New Zealand, October 2010. *Fact File – Health Insurance in New Zealand.* Accessed 8 May 2014. http://www.healthfunds.org.nz/pdf/Fact%20File%20oct2010.pdf

Flecher X, Sporer S, Paprosky W. Management of severe bone loss in acetabular revision using a trabecular metal shell. *J Arthroplasty* 2008;23–7:949

Flecher X, Paprosky W, Grillo J, Aubaniac J, Argenson J. Do tantalum components provide adequate primary fixation in all acetabular revision? *Orthopaedics & Traumatology: Surgery & Researc*h (2010) 96,235-241

Gaver, Ryan, Da Deppo, Lisa, Harri, Eirk and Feinglass, Shamram *"The Total 'Economic Cost' of Revision Total Joint Replacement Surgery in the United States"* (paper presented at 2010 Annual Meeting of American Association of Orthopaedic Surgeons, New Orleans, LA, March 2010)

Gillespie, W.J., Pekarsky, B., and O'Connell, D. L. Evaluation of New Technologies for Total Hip Replacement: Economic Modelling and Clinical Trials*. J. Bone Joint Surg. Br.* 77 (1995), 528

International Federation of Health Plans. "*2012 Comparative Price Report: Variation in Medical and Hospital Prices by Country.*" Accessed January 29, 2014. http://hushp.harvard.edu/sites/default/files/downloadable_files/IFHP%202012%20Comparative%20Price%20Report.pdf

Lakes District DHB. "*Hip Revision Information.*" (Official Information Request, released January 8, 2014) .https://www.fyi.org.nz/request/1352/response/5227/attach/3/2013%2001%2008%20fnl%20Julie%20Hands%20re%20hip%20revision%20surgeries.pdf

Lingaraj K, Teo YH, Bergman N. The management of severe acetabular bone defects in revision hip arthroplasty using modular porous metal components*. J Bone Joint Surg Br* 2009;91–12:1555

Ministry of Health. "*Hip Revision Information.*" (Official Information Request, released January 21, 2014). https://www.fyi.org.nz/request/1350/response/5258/attach/3/OIA%20H201304900%20Ms%20Julie%20Hands.pdf

Nehme A, Lewallen D G, Hanssen A D. Modular porous metal augments for treatment of severe acetabular bone loss during revision hip arthroplasty. *Clin Orthop* 2004;(429):201-8

Paprosky W. Revision of the Acetabular Component. Trabecular Metal in Revision, 2012 http://presentations.icjr-me.com/2012/Hall%20B/Day%203/Dr.%20Wayne%20Paprosky.pdf. Accessed 8 May 2014

Robinson, James, Pozen, Alexis, Tseng, Samuel and Bozic, Kevin. Variability in Cost Associated with Total Hip and Knee Replacement Implants*. J. Bone Joint Surg.* AM 94 (2012): 1693-1698. doi: 10.2106/JBJS.K.00355

Schedule of Surgical Maximums. (Southern Cross, New Zealand, July 29, 2013) https://www.southerncross.co.nz/Portals/0/Society/EFulfillment/Product/Schedule%20of%20Surgical%20Maximums.pdf

Schwarzkopf R, Shah J, Ahmad A, Ready J. Porous Metal Augments Show Excellent Mid-to-Long Term Survival in Complex Acetabular Reconstruction. *J Arthroplasty* (2014), http://dx.doi.org/10.1016/j.arth.2014.03.016

Siegmeth A, Duncan CP, Masri BA, Kim WY, Garbuz DS. Modular tantalum augments for acetabular defects in revision hip arthroplasty. *Clin Orthop Relat Res* 2009;467:199–205

Sporer SM, Paprosky WG. The use of a trabecular metal acetabular component and trabecular metal augment for severe acetabular defects. *J Arthroplasty* 2006;21(Suppl):83–86

Sporer SM, Paprosky WG. Acetabular revision using a trabecular metal acetabular component for severe acetabular bone loss associated with a pelvic discontinuity. *J Arthroplasty* 2006;21(Suppl):87–90

Sporer S, Hulst J, Moric M. Acetabular Distraction. An Alternative for Severe Defects with Chronic Pelvic Discontinuity? *Clin Orthop Relat Res* (2012) 470:3156-3163. doi 10.1007/s11999-012-2514-1

Taylor E, Browne J. Reconstruction options for acetabular revision. *World J Orthop* 18 (2012): 99. Accessed December 14, 2013, doi: 10.5312/wjo.v3.i7.95

The New Zealand Joint Registry: Fourteen Year Report. (Christchurch, New Zealand Orthopaedic Association, 2013)

Tredinnick, S., Body, D., Christensen, A., Kircher, and R. "*Whitepaper: Evaluation of the Functional Osseointegration of Electron Beam Melted Ti6AI.*" (Ossis Ltd, Christchurch, 2013)

Van Kleunen J, Lee G-C, Lementowski P, Nelson C, Garino J. Acetabular Revisions using Trabecular Metal Cups and Augments. *J Arthroplasty* 2009;24(Suppl 1) 64-67

Weeden SH, Schmidt RH. The use of tantalum porous metal implants for Paprosky 3A and 3B defects. *J Arthroplasty* 2007;22–6(Suppl 2):151

Appendix 1: Complex Acetabular Revision Procedure Costs – Public Healthcare System (excl. gst)

	Estimated Current Cost to DHB of a Complex Acetabular Revision using an TM system	**Estimated Incremental Cost/(Cost Saving) to DHB's from the use of an Ossis Component**	**Estimated Cost to DHB of a Complex Acetabular Revision using an Ossis Component**
Hospital Theatre Utilisation	$4,920	$(1,320)	$3,600
Hospital Bed Utilisation	$10,200	$(4,800)	$5,400
Clinician Productivity	$2,945	$(418)	$2,527
Prosthesis Costs	$14,500	$4,220	$18,720
Rehabilitation Costs	$2,371	$(782)	$1,589
Failure/Complication Risk	$2,209	$(2,209)	$0
Total	**$37,145**	**($5,309)**	**$31,836**