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Cost Analysis of Intramedullary Screw versus Plate Osteosynthesis for Phalangeal and Metacarpal Fractures: An Observational Study

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Background: To compare the observed healthcare and societal costs of intramedullary screw (IMS) and plate fixation of extra-articular metacarpal and phalangeal fractures in a contemporary Australian context.

Methods: A retrospective analysis, based on previously published data, was performed utilising information from Australian public and private hospitals, the Medicare Benefits Schedule (MBS) and the Australian Bureau of Statistics.

Results: Plate fixation demonstrated longer surgical lengths (32 minutes, compared to 25 minutes), greater hardware costs (AUD 1,088 vs. AUD 355), more extended follow-up requirements (6.3 months, compared to 5 months) and higher rates of subsequent hardware removal (24% compared to 4.6%), resulting in an increased healthcare expenditure of AUD 1,519.41 in the public system, and AUD 1,698.59 in the private sector. Wage losses were estimated at AUD 15,515.78 when the fracture cohort is fixed by a plate, and AUD 13,542.43 when using an IMS – a differential of AUD 1,973.35.

Conclusions: There is a substantial saving to both the health system and the patient when using IMS fixation over dorsal plating for the fixation of extra-articular metacarpal and phalangeal fractures.

Level of Evidence: Level III (Cost Utility)

Keywords: *Fracture, Hand, Metacarpal, Phalanx, Intramedullary screw, Plate, Fixation, Cost*

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INTRODUCTION

Fractures of the hand are extremely common, comprising almost a fifth of all emergency department presentations.[1] A 13.7% increase in the rate of hand and wrist fractures has been noted in Australasia during the period spanning 1990–2017. The current incidence of 652 hand and wrist fractures per 100,000 population results in approximately 12 disability-adjusted life years (DALYs) for that same cohort, with a resultant significant burden to both the patient and the health system.[2,3] Thus, optimal management of these injuries is key.

Although many of these fractures are stable, and can be adequately managed non-operatively, the mechanism of injury, patient characteristics and fracture pattern may mandate surgical intervention.[4] The optimal surgical modality must balance the need for rigid fixation to allow early movement against extensive soft tissue dissection, with resultant adhesions causing limitations in range of motion and function.[5] A number of options exist, including external fixation, stabilisation via Kirschner-wires (K-wires) or intramedullary screws (IMS) or the utilisation of plate and screw constructs. Plate fixation, while providing adequate stability for early mobilisation, confers an increased risk of adhesions and the need for subsequent plate removal and extensor tenolysis due to the necessary tissue dissection, the intimate relationship between soft tissue and bone and limited cross-sectional area for implant placement in the hand.[4,6–10]

The use of intramedullary cannulated headless compression screw fixation for select extra-articular fractures aims to address the previously conflicting concerns of minimising tendon disturbance and providing adequate construct stability.[11] Although a number of potential disadvantages have been raised (including the learning curve, potential canal-screw mismatch, diminished construct rigidity when compared to plate fixation and injury to the articular surface and extensor tendon), promising early and medium-term outcomes (and a low major complication rate of between 3.2% and 6.0%) have been reported following the use of IMS fixation in initially metacarpal, and more recently, phalangeal fractures[5,12–16] Alternate methods of intramedullary screw insertion have broadened the range of fractures in which this construct can be utilised.[30]

However, surgical choice must also take into consideration the costs associated with each modality. There is currently only one cost analysis of fixation in the setting of hand fractures, with no comparison between IMS and plate fixation.[17] Thus, the aim of this study is to compare the direct healthcare and societal cost of IMS and plate fixation of extra-articular metacarpal and phalangeal fractures in a contemporary Australian context.

METHODS

This study was performed in a retrospective fashion. Given that all data included is publicly available, with no direct participant involvement, institutional ethics approval was not required.

Previously published data comparing outcomes following fixation via either IMS or plate constructs for extra-articular metacarpal or phalangeal fractures in skeletally mature patients were utilised to calculate surgical and follow-up costs for that episode of care, until the patient was discharged from follow-up. Additionally, the societal burden in terms of lost wages while the patient is unable to work was also appraised.[14]

Surgical costs included both that of the prostheses (with average prices obtained from the relevant biomedical companies) and hospital expenditures. Hospital expenditures incorporated operating time, anaesthetist and surgeon fees and follow-up costs. In Australia, a nationally funded healthcare system (Medicare) exists to cover some or all of the cost of healthcare provision in both public and private health systems. In the public system, the entire cost of surgeries is covered as part of a bulk funding agreement between the state-run hospital and the federal government.[18] In the private sector, surgeons can determine the surgical fee, granting patients a rebate towards the cost of care from Medicare and private health insurance companies. The rebated amount is defined by item numbers corresponding to service provision listed on the Medicare Benefits Schedule (MBS) and is claimed during the operation, with the difference covered by the patient. For this study, it was assumed that surgeons would select the MBS item number for open reduction and internal fixation of fracture of phalanx or metacarpal (47310) when using either technique, as the alternate item number for percutaneous fixation with K-wire fixation does not capture IMS insertion.[19]

Anaesthetist fees in the private health sector were based on the Medicare rebate, where there is a charge for the pre-anaesthetic consultation and further reimbursements for each 15-minute block of anaesthesia.[18,20] For simplicity's sake, excess surgeon fees (a 'gap'), varying private health company contributions, and complexities which may incur further anaesthetic costs (such as advanced age, significant comorbidities and emergency after-hours care) were not factored into the calculations.[18,20]

Operating theatre and follow-up expenditures were obtained and averaged from a public tertiary referral hospital and a private hospital in Queensland, Australia. A conservative estimate of 1 hour of theatre time was implemented per potential removal of hardware case, based on previous literature demonstrating mean surgical length of 44.0 minutes.[21] An additional 15 minutes was allocated per case for theatre changeover, based on prior

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data from Queensland noting that over 80% of surgeries required this period for preoperative preparation.[22] To calculate the cost of hardware removal per fixation method, the probability of removal (based on the prior literature) was multiplied by the mean cost of a hardware removal operation.[14]

Similarly, when considering follow-up costs, an estimate of one surgical review, one radiograph and two hand therapy sessions were applied for each month of follow-up. When follow-up was performed through the public healthcare system, a nursing assessment was performed at the initial post-procedure consult to remove sutures and redress the wound as required, while hand therapy input was sought at every appointment to aid in rehabilitation. For private follow-up, the calculated expenditure did not include surgeon consult fees for the initial 6-week postoperative period (as this care is included in the surgical fee), with subsequent reviews incurring a cost; however, all hand therapy sessions required out-of-pocket payments. Mean Australian wage information was also obtained from the Australian Bureau of Statistics and used to project lost wages.[23]

RESULTS

Previously published data by Esteban-Feliu et al comparing outcomes of plate and IMS fixation of metacarpal and phalangeal fractures are presented in Table 1.[14] Longer surgical length, need for follow-up and return to work periods were noted following the utilisation of plates, with an associated greater requirement for hardware removal. Contemporary Australian healthcare costs for both the public and private sectors are presented in Table 2.

Greater operative duration with plate fixation resulted in a further expenditure of AUD 138.53 per case in the public health system, and AUD 145.29 privately. Similarly, the cost of a six-hole locking plate is approximately triple that of a single IMS (AUD 1,088, compared to AUD 355). The significantly higher rate of hardware removal associated with plate fixation (24%) in Esteban-Feliu et al's data during the episode of care (as compared to 3% for IMS utilisation) resulted in a roughly fivefold greater pro-rata follow-up surgery expenditure (AUD 405.53 vs. AUD 73.11 in the public system, and AUD 493.32 as compared to AUD 89.02 privately). Longer follow-up for plate fixation resulted in a cost difference of AUD 315.86 in the public health system, and AUD 416.00 in the private health sector.

Thus, the use of dorsal plate fixation over IMS stabilisation resulted in a mean total additional healthcare expenditure of AUD 1,519.41 in the public system, and AUD 1,698.59 in the private sector (refer Table 3). Wage losses (including those for hardware removal) were estimated at AUD 15,515.78 when the fracture cohort is fixed by a plate, and AUD 13,542.43 when using an IMS – a differential of AUD 1,973.35.

DISCUSSION

The rate of open reduction with stabilisation of metacarpal and phalangeal fractures has risen over the last two decades.[24] Thus, a nuanced understanding of all aspects of various fixation methods is key. Although dorsal plating has traditionally been utilised as fixation of choice in phalangeal and metacarpal fractures, the significant soft tissue dissection and limited cross-sectional area available for prosthesis placement may result in increased

Table 1. Parameters Related to Mode of Fixation[16]

	Intramedullary screw ($n = 62$)	Plate ($n = 124$)	*P*-values
Surgical duration (minutes)	25.09 ± 5.20	32.57 ± 6.71	**<0.001**
Need for hardware removal (%)	3 (4.8)	33 (26.6)	**<0.001**
Follow-up duration (months)	5.0 ± 2.2	6.3 ± 4.2	0.492
Return to work (weeks)	7.7 ± 2.9	8.4 ± 2.8	**0.005**
Type of work *n* (%)			
• Strength	12 (23.1)	28 (22.6)	0.382
• Not strength	40 (76.9)	96 (77.4)	
Type of injury *n* (%)			
• Occupational	2 (3.2)	3 (2.4)	0.189
• Non-occupational	60 (96.2)	121 (97.6)	

Significance levels taken from Esteban-Feliu et al.[16]

Table 2. Current Australian Healthcare Costs

Category	Costing data (AUD)∉
Public theatre time (inclusive of all staff and operational costs)*,±	1,111.11/hour = 18.52/minute (based on $10,000 per 9-hour session)
Private hospital theatre time (inclusive of three staff, electricity, sterilisation and basic equipment)δ	1,000.00/hour = 16.67/minute
Medicare rebate towards private anaesthetistγ	45.40 pre-anaesthetic consultation 20.60 per 15-minute block
Medicare rebate towards private surgeon∇	343.40
Hardware cost IMS (single cannulated headless compression screw + guide wire)Ψ	355.00
Hardware cost six-hole locking plate+ two cortical+ four locking screwsΨ	994.00
Hardware cost six-hole locking plate with all locking screws Ψ	1,088.00
Removal of hardware in public hospital (inclusive procedure cost and single follow-up with orthopaedic, nursing and hand therapy review)*,ǀ	1,523.05
Removal of hardware in private hospital (inclusive procedure cost and single follow-up with orthopaedic and hand therapy review)δ,∀,Ω	1,854.60
Follow-up costs in public system per appointment*	
• Orthopaedic	68.56
• Nursing and wound care	28.82
• Hand therapist	36.78
• Plain radiograph	100.85
Total per appointment (excluding initial nursing review)∅	242.97
Cost of follow-up in private system per appointmentδ	
• Orthopaedic review (beyond 6 weeks)	150.00
• Hand therapy initial review	110.00
• Hand therapy ongoing review	85.00
Mean Australian weekly wageΣ	1,737.10

∉Australian dollars.
*Public tertiary referral hospital, Queensland, Australia.
±Includes orthopaedic consultant and registrar/resident, anaesthetic consultant and registrar/resident, five nursing staff (admission, theatre and recovery) and operational staff. Excludes building costs and electricity.
δPrivate Hospital, Queensland, Australia.
γMBS Item numbers 17610, 21830 and 23010 – Medicare Benefits Schedule (MBS).[18]
∇MBS item number 47310 – MBS.[18]
ΨMean hardware expenditure from common medical manufacturers (Acumed, Hillsboro, Oregon; Medartis, Basel, Switzerland; Synthes Solothurn, Switzerland).
ǀPublic removal of hardware cost = theatre rate per hour × (1 hour procedure + 15 minute theatre changeover time) + single orthopaedic, nursing and hand therapy review = (1,111.11 × 1.25) + (68.56 + 28.82 + 36.78) = 1,523.05.
∀Includes MBS item number 47929 for surgical removal fee (AUD 391.80) – MBS.[18]
ΩPrivate removal of hardware cost = theatre rate per hour × (1 hour procedure + 15 minute theatre changeover time) + (pre-anaesthetic consultation fee + fee per 15 minute unit of care) + surgeon removal fee + single hand therapy review = (1,000 × 1.25) + (45.40 + (20.60 × 4)) + 391.80 + 85 = 1,854.60.
∅Public per month follow-up = one orthopaedic follow-up + two hand therapy reviews + one radiograph.
ΣAustralian Bureau of Statistics.[20]

extensor adhesions and decreased postoperative range of motion (with studies reporting significant stiffness in between 10% and 42% of patients), as well as the need for hardware removal and tenolysis.[4,7,10] The advent of modern low-profile plating systems has yielded mixed results, with some authors reporting diminished rates of re-operation, while others noted similar proportions of patients requiring plate removal and tenolysis.[6,8]

Alternative approaches to minimise invasiveness and extensor tendon impediment, while maintaining adequate biomechanical stability to permit early motion, have been proposed and accepted to varying degrees. Lateral plating via a tendon sparing approach has been shown to result in greater postoperative total active motion (TAM) when compared to dorsal plating.[4] However, perceptions of technical difficulty (due to decreased familiarity with the approach, the need to contour the plate and often poor

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Table 3. Costing Comparison

	Intramedullary screw (AUD)	Plate (six-hole all locking) (AUD)
Surgery cost		
• Public theatre costs[∃]	742.47	881.00
• Private theatre costs[Φ]	1,098.30	1,243.59
• Hardware	355.00	1,088.00
Pro-rata hardware removal[ϑ]		
• Public	73.11	405.13
• Private	89.02	493.32
Follow-up costs		
• Public[^]	1,243.67	1,559.53
• Private[Π]	1,400.00	1,816.00
Total healthcare costs[Σ]		
• Public	2,414.25	3,933.66
• Private	2,942.32	4,640.91
Lost wages[⊗]	13,542.43	15,515.78
Cost difference		
• Public healthcare costs	1,519.41	
• Private healthcare costs	1,698.59	
• Patient (wages lost)	1,973.35	

[∃]Public cost = theatre per minute rate × (duration of procedure + 15 minutes changeover time) = 18.52 × (duration of procedure + 15 minutes).

[Φ]Private cost = theatre per minute rate × (duration of procedure + 15 minute theatre changeover) + (pre-anaesthetic consultation fee + [anaesthetic rate rounded up to nearest 15-minute block of time]) + surgeon fee = 16.67 × (duration of procedure + 15 minutes) + (45.40 + [20.60 × duration of procedure rounded up to nearest 15-minute block]) + 343.40.

[ϑ]Cost = removal of hardware cost × % need for removal.

[^]Public cost = (follow-up per month @ 242.97 × follow-up duration in months) + nursing wound care @28.82.

[Π]Private cost = orthopaedic review @ 150 per month × (follow-up duration in months – 1.5 months covered in initial surgeon fee) + (hand therapy costs @85 per appointment × [follow-up duration in months × two appointments per month – 1]) + initial hand therapy review @110.

[Σ]Total healthcare cost = theatre costs + hardware costs + pro-rata removal of hardware cost + follow-up costs.

[⊗]Lost wages = mean weekly wage × return to work weeks + (mean weekly wage × 2 weeks × need for removal of hardware %) 1,737.10 × return to work weeks + (1,737.10 × 2 × need for removal of hardware %).

visualisation requiring an indirect reduction of the fracture) may limit widespread adoption of lateral plating as a technique. Intramedullary fixation using headless compression screws has enjoyed increasing popularity as a simpler method of achieving stable fixation for select fracture patterns and facilitating early range of motion.[12] Early and mid-term results reveal low rates of secondary operations with positive postoperative functional and patient-reported outcomes. Del Piñal et al reported on a series of 59 patients, and noted that two patients required a tenolysis, with a single patient exhibiting loss of fixation due to unrecognised intra-articular extension. Two other patients underwent intra-operative conversion to plate stabilisation, as IMS was not deemed satisfactory fixation for the comminuted fracture pattern.[13] Poggetti et al described a series of 173 metacarpal or phalangeal fractures in 153 patients treated with IMS fixation – at a mean 4-year follow-up, a single patient required screw removal for intra-articular migration, with four patients demonstrating a mild extension lag of less than 30°.[16] A recent systematic review of IMS fixation of metacarpal and phalangeal fractures found that fracture fixation using IMSs was a quick procedure (mean 26 minutes) with low complication rates and excellent functional outcomes (mean TAM of 243°; mean Disabilities of the Arm, Shoulder and Hand [DASH] score of 3.7 and grip strength of 97% of the contralateral side).[15] This echoed the findings of an earlier systematic review by Sivakumar, which found a mean TAM of 248° and pooled DASH of 3.62 when considering proximal phalanges alone.[5]

Although clinical outcome is the main determinant, many other factors are taken into consideration when deciding on optimal surgical modality.[31] Cost- and time-effectiveness are also key, with many health systems burdened with limited resources. Approximately 10.2% of Australia's gross domestic product (GDP) in 2020 was directed towards health expenditure, with an even high share noted in the United States of America at 19.7%.[25,26] Thus, rationalisation of surgical and rehabilitation cost is key in optimising allocation of limited resources.

Esteban-Feliu et al compared K-wire insertion, IMS stabilisation and plate fixation for extra-articular metacarpal and phalangeal fractures, and found shorter operative durations, quicker return to work and lower rates of secondary operations, with no difference in union or functional outcomes, when intramedullary screws were utilised.[14] These results underpinned our calculations. From a financial perspective, Brewer compared K-wire and IMS fixation of metacarpal and phalangeal fractures, and found no overall difference in total health expenditure.[17] Higher prosthesis costs with IMS fixation was offset by greater imaging and hardware removal expenditures when utilising K-wires. Our study is the first to analyse healthcare costs associated with fixation of extra-articular phalangeal and metacarpal fractures via either dorsal plating or IMS fixation and suggests a higher cost to the health system when a plate is utilised. The additional expenditure is attributed to greater construct cost, longer operative and rehabilitation durations and a more frequent need for removal of hardware with dorsal plating.

Another factor that should be considered (but often is not, due to the siloed nature of medicine) is the economic burden to the patient from a loss of income following an operation. Previous studies have demonstrated a number of factors affecting return to work following orthopaedic and hand surgery operations, including type of operation, postoperative pain, gender, medical claims filed prior to the operation and elevated preoperative post-traumatic stress disorder symptoms.[27,28] This study found a lower economic burden to the patient following the utilisation of IMS fixation, which is likely related to shorter duration of follow-up and less frequent need for hardware removal. These findings should be considered by the clinician during surgical decision making, with appropriate preoperative counselling.

This study has several limitations. It is a direct cost analysis using a number of assumptions, which carry an inherent risk of error; this was offset by the assumptions being conservative in nature. Cost estimates may vary between institute, state and country, and thus the true cost difference will vary between health systems. The study is based in the Australian health system and its findings may not be transferrable to other nations. Performance of a cost-effectiveness analysis utilising incremental cost-effectiveness to quantify quality-of-life outcomes may have been useful but was outside the scope of this study.[29] No statistical analysis was performed, as this study was designed as a purely observational report (based on previous findings by Esteban-Feliu et al), nor was a sensitivity analysis performed – thus, interpretation of cause and effect is limited. Finally, both metacarpals and phalanges were considered together despite the fact that they likely have differing hand therapy and hardware removal requirements, which adds a degree of measurement bias.

However, this report does indicate a substantial cost saving to both the health system and the patient when using IMS fixation over dorsal plating for extra-articular metacarpal and phalangeal fractures by using recently published performance metrics and contemporary Australian costing data. This differential should be taken into account by clinicians and departments when advocating for fixation methods for these fractures. Further prospective or retrospective cost analysis using a comparative cohort of patients would be useful.

DECLARATIONS

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REFERENCES

1. Dias JJ, Garcia-Elias M. Hand injury costs. *Injury*. 2006;37(11):1071–1077. https://doi.org/10.1016/j.injury.2006.07.023.
2. Crowe CS, Massenburg BB, Morrison SD, et al. Global trends of hand and wrist trauma: A systematic analysis of fracture and digit amputation using the Global Burden of Disease 2017 Study. *Inj Prev*. 2020;26(Suppl 1):i115–i124. https://doi.org/10.1136/injuryprev-2019-043495.
3. Robinson LS, Sarkies M, Brown T, O'Brien L. Direct, indirect and intangible costs of acute hand and wrist injuries: A systematic review. *Injury*. 2016;47(12):2614–2626. https://doi.org/10.1016/j.injury.2016.09.041.
4. Sivakumar BS, An VVG, Phan K, et al. Range of motion following extensor tendon splitting vs. tendon sparing approaches for plate osteosynthesis of proximal phalangeal fractures – A systematic review and meta-analysis. *J Hand Surg Asian Pac Vol*. 2020;25(4):462–468. https://doi.org/10.1142/S2424835520500514.
5. Sivakumar BS, An VVG, Graham DJ, Ledgard J, Lawson RD, Furniss D. Intramedullary compression screw fixation of proximal phalangeal fractures: A systematic literature review. *Hand (N Y)*. 2020;17(4):1558944720928503. https://doi.org/10.1177/1558944720928503.
6. Baumgartner RE, Federer AE, Guerrero EM, Mithani SK, Ruch DS, Richard MJ. Complications of low-profile plate fixation in metacarpal fractures. *Orthopedics*. 2021;44(1):e91–e94. https://doi.org/10.3928/01477447-20200925-02.
7. Fusetti C, Meyer H, Borisch N, Stern R, Santa DD, Papaloizos M. Complications of plate fixation in metacarpal fractures. *J Trauma*. 2002;52(3):535–539. https://doi.org/10.1097/00005373-200203000-00019.
8. Guerrero EM, Baumgartner RE, Federer AE, Mithani SK, Ruch DS, Richard MJ. Complications of low-profile plate fixation of phalanx fractures. *Hand (N Y)*. 2021;16(2):248–252. https://doi.org/10.1177/1558944719855684.
9. Page SM, Stern PJ. Complications and range of motion following plate fixation of metacarpal and phalangeal fractures. *J Hand Surg Am*. 1998;23(5):827–832. https://doi.org/10.1016/S0363-5023(98)80157-3.
10. von Kieseritzky J, Nordstrom J, Arner M. Reoperations and postoperative complications after osteosynthesis of phalangeal fractures: A retrospective cohort study. *J Plast Surg Hand Surg*. 2017;51(6):458–462. https://doi.org/10.1080/2000656X.2017.1313261.
11. Cheah AE, Yao J. Hand fractures: Indications, the tried and true and new innovations. *J Hand Surg Am*. 2016;41(6):712–722. https://doi.org/10.1016/j.jhsa.2016.03.007.
12. Chao J, Patel A, Shah A. Intramedullary screw fixation comprehensive technique guide for metacarpal and phalanx fractures: Pearls and pitfalls. *Plast Reconstr Surg Glob Open*. 2021;9(10): e3895. https://doi.org/10.1097/GOX.0000000000003895.
13. del Pinal F, Moraleda E, Ruas JS, de Piero GH, Cerezal L. Minimally invasive fixation of fractures of the phalanges and metacarpals with intramedullary cannulated headless compression screws. *J Hand Surg Am*. 2015;40(4):692–700. https://doi.org/10.1016/j.jhsa.2014.11.023.
14. Esteban-Feliu I, Gallardo-Calero I, Barrera-Ochoa S, Lluch-Bergada A, Alabau-Rodriguez S, Mir-Bullo X. Analysis of 3 different operative techniques for extra-articular fractures of the phalanges and metacarpals. *Hand (N Y)*. 2021;16(5):595–603. https://doi.org/10.1177/1558944719873144.
15. Hug U, Fiumedinisi F, Pallaver A, et al. Intramedullary screw fixation of metacarpal and phalangeal fractures – A systematic review of 837 patients. *Hand Surg Rehabil*. 2021;40(5):622–630. https://doi.org/10.1016/j.hansur.2021.04.009.
16. Poggetti A, Fagetti A, Lauri G, Cherubino M, Borelli PP, Pfanner S. Outcomes of 173 metacarpal and phalangeal fractures treated by intramedullary headless screw fixation with a 4-year follow-up. *J Hand Surg Eur Vol*. 2021;46(5):466–470. https://doi.org/10.1177/1753193420980324.
17. Brewer CF, Young-Sing Q, Sierakowski A. Cost comparison of Kirschner wire versus intramedullary screw fixation of metacarpal and phalangeal fractures. *Hand (N Y)*. 2021: 15589447211030690. https://doi.org/10.1177/15589447211030690.
18. Department of Health and Aged Care, Australian Government. The Australian health system. 2019. Accessed July 3, 2022. https://www.health.gov.au/about-us/the-australian-health-system.
19. Department of Health and Aged Care, Australian Government. Medicare benefits schedule. Accessed March 22, 2022. http://www9.health.gov.au/mbs/search.cfm?q = 47310&sopt=S.
20. Australian Society of Anaesthetists. Health insurance rebates for anaesthesia procedures. Accessed July 3, 2022. https://asapublicaccess.s3.ap-southeast-2.amazonaws.com/website/ASA-Billing-Information_20.8.20.pdf.
21. Ryan C, Dunleavy ML, Burton A, Hennrikus W. Outcomes of hardware removal surgery for children. *Orthopedics*. 2022;45(2):e91–e95. https://doi.org/10.3928/01477447-20220105-06.
22. Queensland Audit Office. Queensland public hospital operating theatre efficiency. Volume 1; report 15: 2015–2016. Accessed July 9, 2022. https://documents.parliament.qld.gov.au/TableOffice/TabledPapers/2016/5516T451.pdf.

23. Australian Bureau of Statistics. Average weekly earnings, Australia – Report. May 2021. Accessed January 3, 2022. https://www.abs.gov.au/statistics/labour/earnings-and-work-hours/average-weekly-earnings-australia/latest-release.
24. Sivakumar BS, An VVG, Symes MJ, Graham DJ, Lawson RD, Clarke E. Temporal trends in the management of metacarpal and phalangeal fractures in the 21st century: An analysis of Australian population-based data. *ANZ J Surg*. 2022;92(10):2655–2660. https://doi.org/10.1111/ans.17818.
25. Australian Institute of Health and Welfare. *Health Expenditure*. Canberra: Australian Institute of Health and Welfare; 2022. Accessed July 8, 2022. https://www.aihw.gov.au/reports/health-welfare-expenditure/health-expenditure.
26. Statista Research Department. U.S. health expenditure as percent of GDP 1960–2020. Accessed July 8, 2022. https://www.statista.com/statistics/184968/us-health-expenditure-as-percent-of-gdp-since-1960/.
27. Hah JM, Lee E, Shrestha R, et al. Return to work and productivity loss after surgery: A health economic evaluation. *Int J Surg*. 2021;95:106100. https://doi.org/10.1016/j.ijsu.2021.106100.
28. Opsteegh L, Reinders-Messelink HA, Schollier D, et al. Determinants of return to work in patients with hand disorders and hand injuries. *J Occup Rehabil*. 2009;19(3):245–255. https://doi.org/10.1007/s10926-009-9181-4.
29. Rajan PV, Qudsi RA, Dyer GSM, Losina E. Cost-utility studies in upper limb orthopaedic surgery: A systematic review of published literature. *Bone Joint J*. 2018;100-B(11):1416–1423. https://doi.org/10.1302/0301-620X.100B11.BJJ-2018-0246.R1.
30. Sivakumar BS, Graham DJ. Reverse instrumentation for headless compression screw fixation of basal proximal phalangeal fractures. *J Hand Surg Am*. February 22, 2023;S0363-5023(23)00002-3. https://doi.org/10.1016/j.jhsa.2022.12.012.
31. Sivakumar BS, Ross M, Graham DJ. Practice variation in proximal phalangeal fracture management. *J Hand Surg Asian Pac*. 2023;28(2):1–5. https://doi.org/10.1142/S2424835523500200.