Acta Scientiarum
http://periodicos.uem.br/ojs
ISSN on-line: 1807-8648
Doi: 10.4025/actascihealthsci.v46i1.64138

MEDICINA / MEDICINE

Orthopedic injuries in a tertiary hospital: an epidemiological and economic analysis of the implants used

Igor Fiorese Vieira[1*], **José Luiz Lopes Vieira**[2], **Luciana Ferreira**[3], **Eric Schmiseila**[4], **Anita Bittar e Silva**[4], **Mateus Strazzi Barreto**[1] **and Sergio Skrobot**[1]

[1]Hospital Universitário Cajuru, Av. São José, Cristo Rei, 80050-350, Curitiba, Paraná, Brasil. [2]Universidad Católica del Maule, Talca, Chile. [3]Universidade Estadual de Maringá, Maringá, Paraná, Brasil. [4]Unidade Básica de Saúde, Colombo, Paraná, Brasil. *Author for correspondence. E-mail: medigorvieira@gmail.com

ABSTRACT. Identifying the cost and prevalence of orthopedic implants used to fix complex fractures. This is a retrospective study whose data analysis was carried out via a digital database from a tertiary trauma hospital in southern Brazil. A total of 481 fractures from 397 patients were included. In total, 479 orthopedic implants were used. Most patients were male (90.65%; n 364) with a mean age of 42.7 years. The lower limbs predominated in the sample with 90.44% prevalence (N = 435). The Ilizarov device was the most used implant (N = 61), mainly in fractures of the tibia diaphyseal region (N = 30), which was the most fractured bone region (N = 105). Considering this specific segment, the universal nail (N = 42) was the most used implant. The Ilizarov device showed the highest cost regarding the implants (6.33 times more expensive than the 3.5mm DCP implant - reference), whereas the femoral nail had an index of 6.09 and the tibial nail of 5.96. The use of conventional materials, that is, the ones with 4.5mm or 3.5mm, proved to be less expensive, however, less used in face of any orthopedic injury. The Ilizarov-type external fixator was the most expensive and most widely used device in the setting of complex orthopedic injuries.

Keywords: Orthopedic implants; complex fractures; tertiary trauma hospital.

Received on june 25, 2022
Accepted on june 06, 2023

Introduction

Traumatic orthopedic injuries account for approximately 11% of the total workday absences due to disability worldwide. Thus, this fact constitutes an important public health problem, especially in low- and middle-income countries, where the scenario of injuries caused by traffic accidents and firearms has constantly been increasing, resulting in important economic downturns (Murray, et al., 2012).

The interest in improving patient care in face of economic issues has led administrators and healthcare organizations, such as The American College of Surgeons-Committee on Trauma (Miclau, Hoogervorst, Shearer, & Schutz, 2018) and the World Health Organization, to recognize the effectiveness of the local science production to improve the development and care of these patients (Nuyens, & McKee, 2005; Minja, et al., 2011).

Specifically, studies have shown that orthopedic surgeons often incorrectly estimate the cost of the implants and tend to underestimate them (Streit, Youssef, Coale, Carpenter, & Marcus, 2013; Okike et al., 2014). As implant costs continue to increase, an increase in the transparency of these values has occurred, which resulted in increasing pressure for better hospital financial administration (Lybrand & Althausen, 2018).

In view of this current scenario, this study aims at retrospectively reviewing the management of complex orthopedic injuries in a tertiary trauma institution of a Brazilian capital. The main purpose is assessing the epidemiology of these injuries and estimating the prevalence of using the orthopedic implants based on the hypothesis that the nails and circular fixators bring greater economic expense compared to the conventional materials (3.5mm and 4.5mm).

Methods

This is a retrospective observational study that reviewed the medical records of the Emergency Room of the Brazilian hospital referred to as *Hospital Universitário Cajuru* (HUC) from January, 2018 to December, 2019. It was approved by the Research Ethics Committee of the Pontifical Catholic University of Paraná under number 08513018.3.3001.0020.

A total of 481 fractures that resulted in 479 orthopedic implants in 397 patients were included in the study. Considering the patients, 364 (90.65%) were male and 33 (9.35%) were female with an average age of 42.7 years. Data were collected from electronic medical records, thus, there was no direct contact with the patients. Any possible exposure of such patients was mitigated by not identifying their names.

The following inclusion criteria were used to include the participants in the study: patients who were victims of trauma, with a fracture evidenced in the report of imaging tests (x-ray or computed tomography) and with subsequent surgical correction by the Trauma and Bone Reconstruction Group of the Orthopedics and Traumatology Service during the period evaluated at the aforementioned hospital. Patients with incomplete data in the medical records, the ones who suffered trauma outside the period assessed, and those who did not require surgical correction as treatment were excluded from the study.

Continuous variables were expressed as mean ± standard deviation and compared by applying Student's t test and Mann-Whitney test. The categorical variables were expressed as percentages and compared by using either the chi-square test or Fisher's exact test, as appropriate. Statistical analyzes were performed with the R project version 3.3.3 program. P values less than 0.05 were considered statistically significant.

Results

The assessment of the 481 fractures observed in 397 patients that resulted in 479 orthopedic implants showed that the upper limbs were affected in 9.56% (n = 46) of the cases and the lower limbs were affected in 90.44% (n = 435). Patients with multiple fractures (two or more) represented 16.37% (n = 65) of the cases. The distribution according to the anatomical segment reached and the implants used are shown in Table 1.

Table 1. Description of the number of fractures and implants used.

Fractures: 481 (UL = 46 / LL = 435)		Implants	
Proximal Humerus	2	4.5mm conventional plate	51
Diaphyseal Humerus	18	4.5mm locking plate	34
Distal Humerus	11	3.5mm conventional plate	44
Clavicle	1	3.5mm locking plate	55
Proximal Forearm	4	Universal Tibial Nail	45
Diaphyseal Forearm	8	Universal Femoral Nail	54
Distal Forearm	2	Universal Humeral Nail	4
Proximal Femur	53	DCS	9
Diaphyseal Femur	89	LISS	29
Distal Femur	46	Philos	1
Proximal Tibia (tibial plateau)	50	Ilizarov	61
Diaphyseal Tibia	105	Herbert	1
Distal Tibia (tibial pestle)	57	7.0mm Cannulated Screw	8
Ankle	14	DFN	21
Pelvic Ring	11	DHS	7
Acetabulum	3	TFN	43
Calcaneus	4	Tube-to-tube External Fixator	9
Talus	3	3.5mm Cannulated Screw	2

UL: Upper Limbs, LL: Lower Limbs, mm: milimeters. DCS: Dynamic Condylar Screw. LISS: Less Invasive Stabilization System, DFN: Distal Femoral Nail, DHS: Dynamic Hip Screw, TFN: Trochanteric Femoral Nail. the authors.

The association between the implant used and the injured segment can be seen in Table 2.

Table 2. Association between the fracture in the injured segment and the implant used.

Fracture	N	Implants	N
Proximal Humerus	2	4.5mm conventional plate (1); locking proximal humerus plate (1)	2
Diaphyseal Humerus	18	3.5mm locking plate (2); 4.5mm conventional plate (10); Humerus IMN (4); Ilizarov (1); 4.5mm locking plate (1)	18
Distal Humerus	11	3.5mm locking plate (5); 3.5mm conventional plate (1); 4.5mm conventional plate (3); Herbert (1); Ilizarov (1)	11
Clavicle	1	3.5mm conventional plate (1)	1
Proximal Forearm	5	3.5mm conventional plate (4); Ilizarov (1)	5
Diaphyseal Forearm	8	3.5mm conventional plate (5); 3.5mm locking plate (2); 4.5mm conventional plate (1)	8
Distal Forearm	2	3.5mm conventional plate (1); 3.5mm locking plate (1)	2
Proximal Femur	54	4.5mm conventional plate (1); 7.0mm Cannulated plate (4); DHS (5); Universal Femoral Nail (2); Trochanteric Femoral Nail (43); Ilizarov (1)	56

Diaphyseal Femur	90	Universal Femoral Nail (54); DCS (2); 4.5mm conventional plate (8); 4.5 locking plate (1); DFN (18); Ilizarov (5); Trochanteric Femoral Nail (1); 3.5mm conventional plate (1)	90
Distal Femur	44	Universal Femoral Nail (2); DFN (1); LISS (28); 3.5mm locking plate (1); 7.0mm Cannulated plate (2); DCS (7); 3.5mm conventional plate (2); Ilizarov (2); Blade Plate (1)	46
Proximal Tibia (tibial plateau)	50	4.5mm locking plate (25); Ilizarov (13); 4.5mm conventional plate (10); 3.5mm locking plate (1); 3.5mm conventional plate (2); Universal Tibial Nail (2); 7.0mm Cannulated plate (2)	55
Diaphyseal Tibia	105	4.5mm locking plate (7); 4.5mm conventional plate (10); Universal Tibial Nail (42); 3.5mm locking plate (11); Ilizarov (30); 3.5mm conventional plate (4); Tube-to-tube EF (1)	105
Distal Tibia (tibial pestle)	58	3.5mm locking plate (36); 3.5mm conventional plate (4); 4.5mm conventional plate (6); 4.5mm locking plate (1); Tube-to-tube EF (1); Universal Tibial Nail (1); Ilizarov (11)	60
Ankle	18	3.5mm conventional plate (11); Tube-to-tube EF (5); Ilizarov (1); 3.5mm locking plate (1)	18
Pelvic Ring	6	Tube-to-tube EF (1); 4.5mm conventional plate (2); 3.5mm conventional plate (4)	7
Acetabulum	3	3.5mm conventional plate (2); Ilizarov (1)	3
Calcaneus	4	3.5mm conventional plate (4)	4
Talus	3	3.5mm conventional plate (1); Cannulated plate 3.5mm (2)	3

mm: milimeter, IMN: Intramedullary Nail, DHS: Dynamic Hip Screw, DFN: Distal Femoral Nail, LISS: Less Invasive Stabilization System, DCS: Dynamic Condylar Screw, EF: External Fixator. the authors.

Under an economic perspective, Table 3 shows the cost of the conventional implants used according to the Management System of the Table of Procedures, Drugs, and OPM (Orthoses, Prostheses and Special Materials) of the Brazilian Unified Healthcare System (SUS) (SIGTAP). It should be highlighted that the cost of locking implants could not be accurately shown due to the unavailability of standard values, given the variety and competition among manufacturers, commercial representatives and other parties interested.

Table 3. Cost of the conventional implants used according to the Management System of the Table of Procedures, Drugs and OPM of SUS (SIGTAP).

Denomination	SUS Value (R$)	Denomination	SUS Value (R$)
Plates			
3.5 mm DCP Plate	183,81	4.5 mm Narrow DCP plate	235,88
4.5 mm Broad DCP Plate	296,13	3.5 mm Hip Reconstruction Plate	299,90
3.5 mm Semitubular Plate	148,40	4.5 mm Hip Reconstruction Plate	325,69
4.5 mm Semitubular Plate	177,20	3.5 mm One Third Tubular Plate or Cane	148,40
Calcaneus Plate	320,61	4.5 mm One Third Tubular Plate or Cane	177,20
3.5 mm T Plate	275,48	2.7 mm T Plate (Micro mini Plate)	131,36
4.5 mm T Plate	326,00	2.7 mm L Plate (Micro mini Plate)	131,36
2.0 mm Micro mini Straight Plate	122,80	2.7 mm Micro mini Semitubular Plate	146,64
3.5 mm L Plate	275,48	4.5 mm Cloverleaf Plate	288,71
4.5 mm L Plate	288,71	3.5 mm Cloverleaf Plate	275,48
4.5 mm Condylar Plate	534,97	3.5 mm Bridge Plate	527,20
4.5 mm Angled Plate	381,95	4.5 mm Bridge Plate	564,13
Locking Plate	564,13	Ellis Plate	275,48
Tomofix Plate	326,00	4.5 mm Tibial Plateau Support Plate	288,71
Volar or Vps Plate	299,90	HDS/CCS Sliding Screw Plate 135° - 150°	764,34
Washer	8,05	HDS/CCS Sliding Screw C Plate 95°	686,27
Anchor	197,60		
Screws			
3.5 mm Cannulated Screw	116,02	1.5 mm Cortical Screw - Micro mini	18,06
4.5 mm Cannulated Screw	102,92	2.0 mm Cortical Screw - Micro mini	15,34
7.0 mm Cannulated Screw	90,29	2.7 mm Cortical Screw - Micro mini	16,94
3.5 mm Cortical Screw	15,34	4.0 mm/3.5 mm Spongy Screw	27,71
4.5 mm Cortical Screw	18,06	6.5 mm Spongy Screw	27,71
Malleolar Screw	21,89	Hebert Screw	257,29
Interference Screw	486,29		
Nails			
Tibial Nail	1.096,39	Long Cephamedullary Nail	989,15
Femoral Nail	1.120,00	Humerus Nail	1.010,56
Short Cephamedullary Nail	936,58		
Fixators			
Wrist External Fixator	561,66	Circular External Fixator (Lrs/Procallus/Ilizarov)	1.163,90

Pelvic Fixator	950,74	Mini External Fixator / Phalanx Fixator	780,00
Linear External Fixator	648,11	Platform-type External Fixator	1.054,91
Hybrid External Fixator	913,16	Schanz Pin	28,45

mm: milimeter, DCP: Dynamic Compression Plate, DHS: Dynamic Hip Screw, CCS: Condylar Compression Screw. the authors.

Table 4 shows the ratio factor between the cost of the implant used in relation to the lowest cost found.

Table 4. Ratio factorof the implant cost.

Implant	Ratio (1 = 183,81)
3.5mm DCP	1
4.5mm Narrow DCP	1.28
4.5mm Broad DCP	1.61
DHS	4.15
DCS	3.73
Ilizarov	6.33
Tibial Nail	5.96
Femoral Nail	6.09
Trochanteric Nail (short x long average value)	5.23

DCP: Dynamic Compression Plate, DHS: Dynamic Hip Screw, DCS: Dynamic Condylar Screw, mm: milimeter. the authors.

In short, Table 3 shows that the fractures of the distal third tibia were the ones that most required the 3.5 mm locking material (N=37, 61.6%), followed by the fractures of the proximal third tibia (N= 25, 45.5%). The circular external fixator (Ilizarov) was the most used implant (N = 61), mainly in fractures of the tibia diaphyseal region (N = 30). The diaphyseal tibia was the most fractured bone region (N = 105), which mainly required the universal nail (N = 42).

Considering the fractures of the diaphyseal tibia (N = 105), approximately 3/4 of these injuries (N = 82, 78%) were treated with universal nails (N = 42) by using the Ilizarov device (N = 30) and 4.5 mm DCP-type material (N = 10). These materials cost an average of R$1,096.39, R$1,163.90 and R$235.88, respectively. From this point of view, a fracture treated with a universal nail costs on average 4.64 times more than a fracture treated with a conventional plate; the Ilizarov device practically equates the cost of a universal nail with the rational number of 1.06.

Regarding the fractures of the diaphyseal femur (N = 89), approximately 4/5 of these injuries (N = 80, 89%) were treated with antegrade femoral nails (N = 54), retrograde femoral nails (N = 18), and 4.5 mm broad DCP-type plates (N=8). The nails are categorized with the same cost, that is, R$ 1.120, whereas the plates cost R$ 296.13. Thus, in general, the nails are 3.78 times more expensive than the plates.

Regarding the fractures of the proximal femur (N = 54), the femoral trochanteric nail was the most used implant (N = 43, 79%) with an average current implant cost at R$ 962.86 (long and short trochanteric nail). The DHS (Dynamic Hip Screw) was the second most used device, (N = 7, 12.96%) with a cost of R$764.34, a material cost ratio of 1.25 times less, that is, the treatment with a femoral trochanteric nail is 25% more expensive for the hospital system.

Considering fractures of the distal femur (N = 44), the DCS plate (Dynamic Condylar Screw) and the LISS (Less Invasive Stabilization System) had the highest sampling percentage (N = 35, 79%) with a total cost of R$ 686.27 per implant. Due to the unavailability of the LISS plate cost, the materials were considered as having the same cost for measurement purposes. Furthermore, the distal femoral nails, which cost R$1,120.00, corresponded to a more costly ratio of 1.63.

In the scenario of the proximal tibia injuries, joint or not, 50 fractures and the use of 55 implants were seen. The locking materials were predominantly used (N=26, 47%) compared to conventional materials (N = 12, 21.82%). The latter have an approximate expenditure of R$ 235.88 against the Ilizarov device (N = 13, 23.63%), which has an approximate expenditure of R$ 1,163.90. Thus, the plates cost 20% of the resources, comparatively.

Regarding injuries of the tibial pestle and distal tibia, 58 fractures and 60 implants were seen. Similar to the scenario of the fractures of the proximal tibia, the locking materials were dominant (N=37, 61.67%). The 3.5 mm conventional materials were used in only 4 patients (6.67%) with an average cost of R$ 183,81, whereas the circular fixators were used in 11 occasions (18.33%), once more with an average cost of R$ 1,163.90, a rational number of 6.33 for higher expenditure on implants in the fixator group.

The upper limb injuries, as well as the fractures of the ankle, pelvic ring, acetabulum, calcaneus and talus were not taken into account for this analysis due to their low prevalence.

Discussion

In Brazil, as well as in other regions worldwide, budgetary expenditures on orthopedic traumatic injuries, especially those related to higher-energy trauma, point to a progressive increase in the cost for public health (Pan et al., 2014; Lv, et al., 2020 ; Trikha, Cabrera, Bansal, Mittal, & Sharma, 2020). The evaluation on the cost-effectiveness of interventions seeks to optimize results with minimization of expenses and support decisions to improve the administration of the healthcare organizations.

Specifically regarding implants, the use of intramedullary nails for the treatment of fractures of the tibia diaphyseal region and femur has already been well documented in the literature, Saied, Ostovar, Mousavi, and Arabnejhad, (2016) pointed to greater complications related to knee pain. Furthermore, their study showed that these implants, from a financial point of view, cost 4.64 times more than extramedullary tutors, that is, if implants with 4.5mm plates were used, the expense would be lower. This reduction in total spending has a significant impact, since it is estimated, for example in the United States of America, that the cost of medical devices for implant purposes was close to US$ 80 billion in 2007 (Burns, Housman, Booth, & Koenig, 2009), and the costs of orthopedic implants alone will increase at an average rate of 9.8% per year. Epidemiological data also indicated that in the United States the open fractures have an annual cost of approximately US$ 230 million (Howard & Court-Brown, 1997).

In Brazil there are no epidemiological statistics that have mapped traumatic orthopedic injuries, their variability rate, distribution by specialty, lethality rate and the economic impact that these injuries and their consequences can bring to the country (Luciano et al., 2018). According to Oliveira, Cruz, and Matos (2018) in Brazil, in epidemiological terms, public expenditure on trauma, including exposed fractures, outweighs all other reasons for hospitalization, mainly because of economic reason due to social security costs with health and labor charges, in addition to the loss of productive capacity (Prata Filho, Mibielli & Silos, 2018).

In the scenario of joint injuries, mainly the injury of the distal metaphyseal tibia, fixation with a nail has advantages, such as a lower rate of superficial infections and better ankle function, whereas the plates have a lower rate of pain in the knee and better surgical reduction (Hu et al., 2019). According to the results found in the present study, the locking plates were highly used compared to conventional materials and circular external fixators; thus, using implants that minimize the cost/effectiveness ratio is a challenge. Regarding the fractures of proximal tibias, a recent meta-analysis showed a possible superiority in the use of internal synthesis over external fixators in the sense of functionality and post-traumatic arthrosis (Malik-Tabassum et al., 2019).

Recently, Payne et al. (2015) have shown the economic importance of the implants wasted in the scenario of orthopedic surgeries, however, there are few studies that analyze the cost-benefit ratio or the cost related to the implant for these types of fractures. In addition, little knowledge on the cost related to the implant by the orthopedic surgeon is precarious (Okike et al., 2014; Arliani et al., 2016) and minimized by the public healthcare administrators themselves (Albersheim et al., 2020).

Considering the fractures of the proximal femur, the use of intramedullary tutors is notoriously more effective than extramedullary devices (Yu, Chongjun, Xiaowei, & Yu, 2020). However, good surgical indication according to the clinical and radiographic evaluation, as well as the systematic categorization of the lesion, has an impact on the functional outcome and the cost-effectiveness of the implant (Swart, Makhni, Macaulay, Rosenwasser, & Bozic, 2014).

The use of external fixators is classically indicated for extensive soft tissue injuries, bone loss and multifragmented fractures with joint extension (Ruedi, Buckley, & Moran, 2017). The ‘Fix and Flap’ approach is an option for their ever-decreasing use, which consists of treating soft tissue and bone injuries at the same surgical time, and which has already shown good results even for the most complex injuries (Gopal et al., 2000; Singh, Dhillon, & Dhatt, 2020). This converges the fact of choosing internal devices as an alternative which, as shown in this study, are better options from a financial perspective.

Some important social contexts should be mentioned, that is, the orthopedic injuries, which have already been considered as a public health problem in the country (Santos, Fonseca, Cavalcante, & Lima, 2016), and every effort to promote improvement in the quality of care for these patients in a cost-effective way. This finding was highlighted by Arliani et al. (2016) who emphasized that cost reduction is related to effective communication and interaction among physicians, hospitals and supplier companies, in addition to guidance and awareness programs for physicians who are the key players in this scenario. In the current scenario, Sinkler, Flanagan, Joseph, and & Vallier (2023) states that even orthopedic surgery residents receive little education on health economics and they feel unfamiliar, thus, there might be a role for formal economic education.

As a relevant practical application, the present study enables orthopedic surgeons who have little knowledge on the costs of orthopedic implant devices to perceive the difference in costs, as suggested by Streit et al., (2013) and to actively participate in cost-cutting in a healthcare environment, so that spending is intensely scrutinized, resulting in a thorough understanding on implant medical device pricing. This study provides the literature with data and values regarding the epidemiology of orthopedic trauma of the population and its form of treatment in the orthopedics and traumatology service.

The present study has some limitations, that is, the patients were not clinically evaluated, and the measures to quantify or qualify the severity of the traumas were not adopted. Only the injuries treated by the group of orthopedists specialized in trauma and bone reconstruction were shown, without specifying the filter adopted by these surgeons. In addition, it was not possible to carry out an economic analysis on the cost of the locking materials due to their public unavailability, a fact that limited the power of analysis. It should be highlighted that the study was not intended to evaluate the surgical strategy or the selection of implants, but to encourage questioning about the economic bias and emphasize the importance of cost in the context of public health.

Conclusion

In conclusion, the use of 4.5mm or 3.5mm conventional materials proved to be less expensive and less used in any complex orthopedic injury. The Ilizarov device was the most expensive and also the most universally used. For comparison purposes, if 4.5 mm broad dynamic compression plates had been used for the treatment of patients submitted to fixation with femoral intramedullary nail, and 4.5 mm narrow dynamic compression plates for the treatment of patients submitted to tibial intramedullary nail, the initial difference in implant costs would be 73.55% and 78.48%, respectively (approximately one fifth of the cost).

Further studies that correlate the functional and economic impact associated with clinical indications are needed to elucidate the subject and, consequently, provide the healthcare services with information in order to optimize the processes, improve outcomes and strengthen the rational use of resources.

References

Albersheim, M., Parikh, H. R., Peck, S. C., Lindell, J. S., Vang, S., Blaschke, B. L., ... Cunningham, B. P. (2020). Orthopaedic implant cost perceptions: a survey of surgeons and healthcare administrators. *Current Orthopaedic Practice, 31*(5), 489-493. DOI: https://doi.org/10.1097/BCO.0000000000000918

Arliani, G. G., Sabongi, R. G., Batista, A. F., Astur, D. C., Falotico, G. G.,& Cohen, M. (2016). Evaluation of the knowledge on cost of orthopedic implants among orthopedic surgeons. *Acta Ortopaedic Brasileira, 24*(4), 217-221. DOI: https://doi.org/10.1590/1413-785220162404153822

Burns, L. R., Housman, M. G., Booth, R. E., & Koenig, A. (2009). Implant vendors and hospitals: competing influences over product choice by orthopedic surgeons. *Health Care Manage Review, 34*(1), 2–18. DOI: https://doi.org/10.1097/01.hmr.0000342984.22426.ac

Gopal, S., Majumder, S., Batchelor, A. G., Knight, S. L., De Boer. P., & Smith, R. M. (2000). Fix and flap: the radical orthopaedic and plastic treatment of severe open fractures of the tibia. *The Journal of Bone and Joint Surgery (British)2000, 82*(7), 959-966. DOI: https://doi.org/10.1302/0301-620x.82b7.10482

Howard, M., & Court-Brown, C. M. (1997). Epidemiology and management of open frantures of the lower limb. *British Journal of Hospital Medicine, 57*(11), 582-587.

Hu, L., Xiong, Y., Mi, B., Panayi, A. C., Zhou, W., Liu, Y., ... Liu, G. (2019). Comparison of intramedullary nailing and plate fixation in distal tibial fractures with metaphyseal damage: a meta-analysis of randomized controlled trials. *Journal of Orthopaedic Surgeon Research, 14*(1), 30. DOI: https://doi.org/10.1186/s13018-018-1037-1

Luciano, A. P., Almeida, T. C. D. C., Dos Santos Figueiredo, F. W., Schoueri, J. H. M., Abreu, L. C., & Adami, F. (2018). Study of the evolution and variability of nontraumatic orthopedic surgeries in Brazil-9 years of follow-up: A database study. *Medicine*, *97*(21). DOI: https://doi.org/10.1097/md.0000000000010703

Lv, H., Chen, W., Zhang, T., Hou, Z., Yang, G., Zhu, Y., ... Zhang, Y. (2020). Traumatic fractures in China from 2012 to 2014: a National Survey of 512,187 individuals. *Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA, 31*(11), 2167-2178. DOI: https://doi.org/10.1007/s00198-020-05496-9

Lybrand, K. E., & Althausen, P. L. (2018). The role of value-Based implants in orthopedic trauma. *The Orthopedic Clinics of North America, 49*(4), 437-443. DOI: https://doi.org/10.1016/j.ocl.2018.05.005

Malik-Tabassum, K., Pillai, K., Hussain, Y., Bleibleh, S., Babu. S., Giannoudis, P.V.,& Tosounidis, T. H. (2020). Post-operative outcomes of open reduction and internal fixation versus circular external fixation in treatment of tibial plafond fractures: A systematic review and meta-analysis. *Injury, 51*(7), 1448-1456. DOI: https://doi.org/10.1016/j.injury.2020.04.056

Miclau, T., Hoogervorst, P., Shearer, D. W., & Schutz, M. (2018). Current Status of Musculoskeletal Trauma Care Systems Worldwide. *Journal of Orthopaedic Trauma, 32*(Suppl 7), S64-S70. DOI: https://doi.org/10.1097/bot.0000000000001301

Minja, H., Nsanzabana, C., Maure, C., Hoffmann, A., Rumisha, S., Ogundahunsi, O., ... Launois, P. (2011). Impact of health research capacity strengthening in low- and middle-income countries: the case of WHO/TDR programmes. *PLoS Neglected Tropical Diseases, 5*(10). DOI: https://doi.org/10.1371/journal.pntd.0001351

Murray, C. J., Vos, T., Lozano, R., Naghavi, M., Flaxman, A. D., Michaud, C., ... Memish, Z. A. (2012). Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet, 380*(9859), 2197–2223. DOI: https://doi.org/10.1016/S0140-6736(12)61689-4

Nuyens, Y., & McKee, N. A. (2005). No Development Without Research: A challenge for research capacity strengthening. *Global Forum for Health Research*, 1-56. Retrieved from https://api.semanticscholar.org/CorpusID:167580068

Okike, K., O'Toole, R. V., Pollak, A. N., Bishop, J. A., McAndrew, C. M., Mehta, S., ... Lebrun, C. T. (2014). Survey finds few orthopedic surgeons know the costs of the devices they implant. *Health Aff (Millwood), 33*(1), 103-109. DOI: https://doi.org/10.1377/hlthaff.2013.0453

Oliveira, R.V., Cruz, L. P., & Matos, M. A. (2018). Comparative accuracy assessment of the Gustilo and Tscherne classification systems as predictors of infection in open fractures. *Revista Brasileira de Ortopedia, 53*(3), 314-318. DOI: https://doi.org/10.1016/j.rboe.2018.03.005.

Pan, R. H., Chang, N. T., Chu, D., Hsu, K. F., Hsu, Y. N., Hsu, J. C., ... Yang, N. P. (2014). Epidemiology of orthopedic fractures and other injuries among inpatients admitted due to traffic accidents: a 10-year nationwide survey in Taiwan. *The Scientific World Journal*, *5*. DOI: https://doi.org/10.1155/2014/637872

Payne, A., Slover, J., Inneh, I., Hutzler, L., Iorio, R.,& Bosco, J. A. (2015). Orthopedic implant waste: analysis and quantification. *American Journal of Orthopaedic (Belle Mead NJ), 44*(12), 554-560.

Prata Filho, C., Mibielli, M. A. N., & Silos, S. S. (2018). Epidemiologia das fraturas expostas no Hospital das Clínicas de Teresópolis Constantino Ottaviano (HCTCO)- RJ. *Revista da Faculdade de Medicina de Teresópolis, 2*(2), 113-123.

Ruedi, T., Buckley, R. E., & Moran, C. (2017). *Principles of fracture management* (3a ed.). Davos Platz, Switzerland: AO Foundation, Stuttgart, Germany; New York, NY: Distribution by Georg Thieme Verlag.

Saied, A., Ostovar, M., Mousavi, A. A., & Arabnejhad, F. (2016). Comparison of intramedullary nail and plating in treatment of diaphyseal tibial fractures with intact fibulae: A randomized controlled trial. *Indian Journal of Orthopaedic, 50*(3), 277-282. DOI: https://doi.org/10.4103/0019-5413.181793

Santos, L. F. S., Fonseca, J. M., Cavalcante, B. L.S.,& Lima, C. M. (2016). Estudo epidemiológico do trauma ortopédico em um serviço público de emergência. *Caderno de Saúde Coletiva,* Rio de Janeiro, 24 (4), 397-403. DOI: 10.1590/1414-462X201600040128.

Singh, J., Dhillon, M. S.,& Dhatt, S. S. (2020). Single-stage (fix and flap) gives good outcomes in grade 3B/C open tibial fractures: A Prospective Study. *Malaysian Orthopaedic Journal, 14*(1), 61-73. DOI: https://doi.org/10.5704/moj.2003.010

Sinkler, M. A., Flanagan, C. D., Joseph, N. M., & Vallier, H. A. (2023). Orthopaedic surgery residents report little subjective or objective familiarity with healthcare costs. *European Journal of Orthopaedic Surgery & Traumatology: Orthopedie Traumatology, 33*(8), 3475-3481. DOI: https://doi.org/10.1007/s00590-023-03545-7

Streit, J. J., Youssef, A., Coale, R. M, Carpenter, J. E.,& Marcus, R. E. (2013). Orthopaedic surgeons frequently underestimate the cost of orthopedic implants. *Clinical Orthopaedics and Related Research, 471*(6), 1744–1749. DOI: https://doi.org/10.1007/s11999-012-2757-x

Swart, E., Makhni, E. C., Macaulay, W., Rosenwasser, M. P., & Bozic, K. J. (2014). Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. *The Journal of Bone and Joint Surgery*, 96(19), 1612-1620. DOI: https://doi.org/10.2106/jbjs.m.00603. PMID: 25274786.

Trikha, V. V, G., Cabrera, D., Bansal, H., Mittal, S., & Sharma, V. (2020). Epidemiological assessment of acetabular fractures in a level one trauma centre: A 7-Year observational study. *Journal of Clinical Orthopaedics and Trauma, 11*(6), 1104-1109. DOI: https://doi.org/10.1016/j.jcot.2020.09.009

Yu, Z., Chongjun, X., Xiaowei, M., & Yu, X. (2020). Clinical Efficacy of intramedullary fixation vs. plate fixation for femoral intertrochanteric fractures. *Research Square,* 1-9. DOI: https://doi.org/10.21203/rs.3.rs-19534/v1