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Exploring Knee Surgeons' Perspectives on 3D Printing

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Abstract

Three-dimensional printing technology has been developed and applied in orthopedic surgery, including knee arthroplasty. To match individual knee morphology, surgeons can choose between standardized implants or customized 3D-printed ones. Despite technical advancements, the routine adoption of 3D-printed implants faces slow progress and various barriers. Our study explores surgeons' perspectives on 3D-printed prostheses by inviting them to freely express their thoughts by answering the question “What do you think about the manufacture of a prosthesis by 3D printing?

The questionnaire was completed by 90 surgeons, with an average experience exceeding 10 years (57.8% ± 10.2%). The majority worked in public hospitals (60% ± 10.1%) and performed zero to 100 prostheses annually (66.7% ± 9.7%). A large proportion do not use planning software (52.2% ± 9.7%), navigation systems, or robots (68.9% ± 9.6%). Respondents collectively agreed on the additional surgical time necessitated by technological innovation (74.4% ± 9.0%). Opinions on 3D printing were diverse, with 70%± 9.5% expressing positivity and 30%± 9.5% holding negative views. Motivations were categorized into seven domains, centered around "pre-surgery" and "post-surgery" concerns. Notably, results showed that a favorable disposition towards 3D printing was associated with the use of navigation systems or robots.

In conclusion, while no outright opposition to implementation was found, some surgeons expressed a preference for validated results and raised concerns about the entire supply chain, encompassing hospitals, insurance companies, and manufacturers. Despite the absence of opposition, the full adoption of 3D printing in joint replacement hinges on advancements across various areas of joint surgery.

1 Introduction

Three-dimensional printing (3DP), also known as additive manufacturing, originated in the early 1980s. In orthopedics, its use has experienced exponential growth in recent years. This technology allows for the production of customized tools, such as Personalized Surgery Instruments (PSI), representing around two-thirds of 3D printing applications, and customized implants (CI) that make up roughly 10% of the total applications [1–3].

Total knee arthroplasty is the predominant procedure in knee surgery; however, dissatisfaction occurs in 20% of cases, leading to revision in 8 to 12% of patients [4,5]. Revisions typically stem from factors such as infection, mechanical loosening (including issues like instability and malalignment), and polyethylene wear [5].

A more individualized approach could potentially minimize these issues, as the positioning and fit of knee prostheses significantly impact patients' functional outcomes. Currently, surgeons primarily utilize conventional, off-the-shelf implants (OTS) with various sizes and models to match knee morphology. However, these implants, based on standardized anthropometric measurements, may not fully consider individual characteristics [6,7]. To address this issue, CI were developed using 3D-printing technology. However, while numerous studies have highlighted their potential advantages (improving mechanical alignment, implant fit, bone coverage, axial rotation, etc…), recent research has yielded conflicting results [6,8,9].

Given the potential advantages of 3DP over conventional processing technologies, its limited adoption by surgeons is questionable. Understanding the discrepancy between observed technological developments and their slow adoption in practice is of paramount importance. To the best of our knowledge, no study has addressed the surgeon’s point of view. This study aims to identify surgeons’ thoughts on 3DP by investigating and analyzing their opinions and social representations.

2 Material and Methods

A questionnaire was randomly distributed to French surgeons: (1) via an online survey, facilitated through the French National Orthopedic Society, and a regional congress. To achieve our objective, we concentrated on the unique open-ended question, “What do you think about manufacturing a prosthesis using 3DP?”, enabling surgeons to freely express their opinions.

To this common approach used in public health, a complementary approach rooted in language science was introduced. We performed a discourse analysis of the entire corpus of answers to the open-ended question, examining lexicon (which words were used?), semantics (what they referred to), syntactic parameters (sentence configuration), and enunciative point of view (how surgeons expressed their views).

This led us to establish a primary criterion for categorizing surgeons' opinions (positive or negative) and a secondary criterion for justifying each opinion (whether it was supported by a motivation or not). Motivations were then categorized into seven groups (Surgery, Cost, Logistics, Material, Time, Regulatory, Customization) and further classified into pre, intra, and post-operative phases.

Chi-squared test and logistic regression were used to analyzed the data.

3 Results

The questionnaire was completed by 90 surgeons, with an average experience exceeding 10 years (57.8% ± 10.2%). The majority worked in public hospitals (60% ± 10.1%) and performed zero to 100 prostheses annually (66.7% ± 9.7%). A large proportion do not use planning software (52.2% ± 9.7%), navigation systems, or robots (68.9% ± 9.6%). Respondents collectively agreed on the additional surgical time necessitated by technological innovation (74.4% ± 9.0%).

Of the 90 received questionnaires, 17 left the open-ended question unanswered. Among the remaining 73 responses, opinions on 3D printing varied, with 70% ± 9.5% expressing positivity and 30% ± 9.5% holding negative views. No significant relationship was found between categorical variables and opinions (positive or negative) ($p > 0.05$), considering factors like experience, working structure, number of prostheses per year, and use of planning software. However, a significant p-value was observed for the variables "use of navigation or robotics" and "extra surgical time" (Table 1).

	3DP Expressed Opinion			
	Negative, *n* = 22 [1]	**Positive, *n* = 51** [1]	**Total, *n* = 73** [1]	***p*-Value** [2]
Experience (years)				0.8
≤10	9 (41%)	19 (37%)	28 (38%)	
More than 10	13 (59%)	32 (63%)	45 (62%)	
Working structure				0.8
Private	9 (41%)	19 (37%)	28 (38%)	
Public	13 (59%)	32 (63%)	45 (62%)	
Number of prostheses per year				0.4
≤100	16 (73%)	32 (63%)	48 (66%)	
>100	6 (27%)	19 (37%)	25 (34%)	
Use of planning software				>0.9
Yes	11 (50%)	25 (49%)	36 (49%)	
No	11 (50%)	26 (51%)	37 (51%)	
Use of navigation system or robot				0.022
Yes	3 (14%)	21 (41%)	24 (33%)	
No	19 (86%)	30 (59%)	49 (67%)	
Extra surgical time				0.034
Yes	13 (59%)	42 (82%)	55 (75%)	
No	9 (41%)	9 (18%)	18 (25%)	

Table 1: Opinions expressed regarding surgeons' sociodemographics and technology usage.

Logistic regression revealed a likely association between the “use of navigation or robot” and a higher likelihood of positive opinions on 3DP, as indicated by an odds ratio with a p-value of 0.05. The variable “additional surgical time” had no significant impact ($p \geq 0.1$).

When categorizing motivations (table 2), surgery led (39.1%), followed by materials (15.2%), costs (10.9%), logistics (10.9%), time (8.7%), customization (8.7%), and regulatory concerns (6.5%). Positive motivations centered on surgery and customization (anatomical and technical aspects), while negative motivations focused on surgery and materials (strength and lifespan). For surgery stages, pre-operative factors constituted 58.5% and post-operative factors 31.7%.

	POSITIVE		NEGATIVE		Total
	n	**%**	***n***	**%**	***n***
Explicit motivation	51	70%	22	30%	73
YES	24	47%	15	68%	39
NO	27	53%	7	32%	34
Classification of motivation					
Surgery	11	46%	7	47%	18
Costs	3	13%	2	13%	5
Logistics	2	8%	3	20%	5
Materials	2	8%	5	33%	7
Customization	4	17%	-	-	-
Time	3	13%	1	7%	4
Regulatory	-	-	3	20%	-
Sub-total	25	-	21	-	46
Motivation and stage of surgery					
Pre	15	63%	9	60%	24
Intra	3	13%	1	7%	4
Post	7	29%	6	40%	13
Sub-total	25	-	16	-	41

Table 2: Expressed motivations related to the justification of opinions.

Beyond statistics, the syntactic study found that most positive responses were brief or combined spontaneous confidence with concerns, such as “excellent”; “it may be the future” or “is a good solution if it meets current standards”.

Negative responses ranged from explicit dismissal (“useless”; “insignificant”) to skepticism, including pointing out concerns (“fragility”; “lifespan issue”), posing questions about mechanical strength, expressing doubts about material quality, and providing a direct expression of caution (“prudence, prudence”).

4 Conclusion

In our study, two-thirds of surgeons had “positive opinions”, while one-third had “negative opinions”, prioritizing the surgical environment, with the procedure itself rarely being an issue. Both groups generally avoided navigation or robotic systems but were willing to extend surgery time. The use of planning software was equally distributed between users and non-users.

However, among all variables, only the use of navigation or robotic systems might have an impact on opinions. Yet, its exact influence needs clarification through the study of a larger sample size.

In the last two decades, Computer-Assisted Orthopedic Surgery (CAOS), including navigation systems or robots, increased by 154% from 2008 to 2015. Currently, 18% of knee surgeons use these technologies [8], with anticipated further growth [10]. Surgeons' familiarity with the additional time required for procedures [11] may explain the observed confounding effect between extra time and the use of CAOS technology.

Beyond this, our results align with previous studies, emphasizing the significant influence of surgeons' recommendations [8] on CI adoption. Limited evidence regarding CI's superiority over OTS implants has kept surgeons in a “wait-and-see” stance, maintaining their current practices. Further clinical trials are anticipated to establish the long-term superiority of CI [6,9,12,13].

Besides the main factor, other external considerations such as costs, legal issues, and familiarity with OTS implants (training, experience, and comfort) need to be taken into account [8].

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6 References

[1] Andrés-Cano P, Calvo-Haro JA, Fillat-Gomà F, Andrés-Cano I, Perez-Mañanes R. Role of the orthopaedic surgeon in 3D printing: current applications and legal issues for a personalized medicine. Revista Española de Cirugía Ortopédica y Traumatología (English Edition) 2021;65:138–51. https://doi.org/10.1016/j.recote.2021.01.001.

[2] Duan X, Wang B, Yang L, Kadakia AR. Applications of 3D Printing Technology in Orthopedic Treatment. BioMed Research International 2021;2021:e9892456. https://doi.org/10.1155/2021/9892456.

[3] Tack P, Victor J, Gemmel P, Annemans L. 3D-printing techniques in a medical setting: a systematic literature review. BioMed Eng OnLine 2016;15:115. https://doi.org/10.1186/s12938-016-0236-4.

[4] Carr AJ, Robertsson O, Graves S, Price AJ, Arden NK, Judge A, et al. Knee replacement. The Lancet 2012;379:1331–40. https://doi.org/10.1016/S0140-6736(11)60752-6.

[5] Dalury DF, Pomeroy DL, Gorab RS, Adams MJ. Why are Total Knee Arthroplasties Being Revised? The Journal of Arthroplasty 2013;28:120–1. https://doi.org/10.1016/j.arth.2013.04.051.

[6] Moret CS, Hirschmann MT, Vogel N, Arnold MP. Customised, individually made total knee arthroplasty shows promising 1-year clinical and patient reported outcomes. Arch Orthop Trauma Surg 2021;141:2217–25. https://doi.org/10.1007/s00402-021-04045-1.

[7] Budhiparama NC, Lumban-Gaol I, Ifran NN, de Groot PCJ, Nelissen RGHH. Anthropometric Measurement of Caucasian and Asian Knees, Mismatch with Knee Systems? Orthopaedic Journal of Sports Medicine 2020;8:2325967120S00104. https://doi.org/10.1177/2325967120S00104.

[8] Namin AT, Jalali MS, Vahdat V, Bedair HS, O'Connor MI, Kamarthi S, et al. Adoption of New Medical Technologies: The Case of Customized Individually Made Knee Implants. Value in Health 2019;22:423–30. https://doi.org/10.1016/j.jval.2019.01.008.

[9] Beit Ner E, Dosani S, Biant LC, Tawy GF. Custom Implants in TKA Provide No Substantial Benefit in Terms of Outcome Scores, Reoperation Risk, or Mean Alignment: A Systematic Review. Clinical Orthopaedics and Related Research® 2021;479:1237–49. https://doi.org/10.1097/CORR.0000000000001651.

[10] Lan Y-T, Chen Y-W, Niu R, Chang DC, Hollenbeck BL, Mattingly DA, et al. The trend and future projection of technology-assisted total knee arthroplasty in the United States. The International Journal of Medical Robotics and Computer Assisted Surgery n.d.;n/a:e2478. https://doi.org/10.1002/rcs.2478.

[11] Sousa PL, Sculco PK, Mayman DJ, Jerabek SA, Ast MP, Chalmers BP. Robots in the Operating Room During Hip and Knee Arthroplasty. Curr Rev Musculoskelet Med 2020;13:309–17. https://doi.org/10.1007/s12178-020-09625-z.

[12] Culler SD, Martin GM, Swearingen A. Comparison of adverse events rates and hospital cost between customized individually made implants and standard off-the-shelf implants for total knee arthroplasty. Arthroplasty Today 2017;3:257–63. https://doi.org/10.1016/j.artd.2017.05.001.

[13] Schwarzkopf R, Brodsky M, Garcia GA, Gomoll AH. Surgical and Functional Outcomes in Patients Undergoing Total Knee Replacement With Patient-Specific Implants Compared With "Off-the-Shelf" Implants. Orthopaedic Journal of Sports Medicine 2015;3:2325967115590379. https://doi.org/10.1177/2325967115590379.