

Risk Factors for Microbial Contamination of Reusable Suction Tips in Total Joint Arthroplasty: A Prospective Cohort Study

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Abstract

Introduction

Bacterial infection following joint arthroplasty can have catastrophic results. While maintaining strict sterility is critical, the role of reusable suction tips as a potential source of infection remains underinvestigated. The purpose of this study was to identify risk factors associated with the bacterial contamination of reusable suction tips in patients undergoing primary total joint arthroplasty under standard ultraclean operating room conditions.

Materials and methods

A prospective cohort study was conducted on 138 patients who underwent primary total joint arthroplasty between December 2021 and March 2022. For each procedure, two reusable suction tips treated with identical sterilization protocols were prepared. One tip was cultured preoperatively and excluded from use, while the other was utilized during the surgery and cultured postoperatively. All surgeries were performed in an optimized environment utilizing continuous high-pressure suction and enhanced heating, ventilation, and air conditioning (HVAC) systems equipped with high-efficiency particulate absorbing (HEPA) filters and laminar airflow.

Results

Preoperative cultures yielded positive bacterial findings in seven cases (5.1%). In contrast, postoperative cultures demonstrated bacterial contamination in only two cases (1.4%). Notably, none of the patients with positive preoperative cultures exhibited positive findings postoperatively. Both instances of postoperative microbial contamination occurred exclusively in procedures with an operative duration exceeding three hours (186 and 280 minutes, respectively).

Conclusions

The microbial contamination of reusable suction tips during joint arthroplasty is closely related to prolonged operative durations exceeding three hours. To effectively mitigate these infection risks, strict surgical time management and rigorous instrument sterilization protocols are imperative. Furthermore, transitioning to single-use disposable suction tips and maintaining an optimized operating room environment with advanced HVAC systems are strongly recommended.

Level of evidence: Level II

Introduction

As both elderly populations and life expectancy increase rapidly, the absolute numbers and rates of joint replacement surgery are increasing as well. This situation is not limited to a specific joint; rather, hip,

knee, and shoulder joint surgery are all considered to be problems [19; 26; 31]. Also, the numbers of these surgeries are expected to continue increasing over the next decade [15; 16; 23].

Total joint arthroplasty (TJA) has excellent value compared with other common health interventions over the long term because of its high success rate and cost-effectiveness [2]. However, there are some major postoperative complications that can affect primary outcomes such as death, on ventilator care, unplanned intubation, stroke/cerebrovascular accident, deep vein thrombosis (DVT), pulmonary thromboembolism (PTE), cardiac arrest, myocardial infarction (MI), acute renal failure (ARF) requiring dialysis, sepsis, wound dehiscence, and superficial or deep wound infection [28]. One of the most important challenges faced by orthopedic surgeons is periprosthetic joint infection (PJI).

PJI is a well-known complication that can have catastrophic results and a common cause of total joint arthroplasty failure with an incidence of 0.3–1.9% [14; 20]. The reasons could be patient factors or surgical factors. Patient factors include a body mass index (BMI) of ≥ 35 , diabetes mellitus, male sex, an American Society of Anesthesiologists (ASA) score of ≥ 3 , and a diagnosis of osteonecrosis or posttraumatic arthritis [20]. Surgical factors include extensive surgical site exposure and the length of the operation [18]. Sterile surgical devices and environment are also critical for total joint arthroplasty, where the devices consist of iodine foils, chlorohexidine-based solution, surgical drapes, spacesuit technology, high-efficiency particulate absorbing (HEPA) filter, laminar air flow, a method of minimization fluid residue, and sterile suction tips [7].

Regarding surgical instrument contamination, several studies have shown the presence of distinct bacterial charges on surgical gloves, fluid collection bags, and suction tips [1; 7; 8; 21]. Changing gloves regularly is known to be an effective way to reduce the occurrence of glove punctures and bacterial contamination [1]. Furthermore, because bacterial replication usually occurs in humid conditions, studies have also been conducted to determine whether the irrigation fluid reservoir on the surgical cover is subject to bacterial colonization. Fluid surgical drape reservoirs showed marked bacterial contamination over time [7], and practitioners now recommend avoiding irrigation fluid reservoirs [6; 21].

There may be various sources of infection, and there are several studies suggesting that suction tips may be a potential source of infection. In early studies, there were studies that the suction tip could be a source of infection, but the sample size was small and the detailed setting of the operating room situation was lacking [9; 24]. Previous studies were reporting positive rate of 7.8–54% from the disposable suction tips at the end of the surgery [6–8; 12]. The wide range of positive rates is thought to be due to the different circumstances of the operating rooms in each study and the different natures of the studies. Notably, no investigators studied reusable suction tips.

In orthopedic surgery, bacterial infection can have catastrophic results, especially in joint arthroplasty, and for this reason, good results can be achieved only when all possible causes of infection are blocked and the operation is carried out under strict aseptic conditions. The purpose of this study was to identify risk factors associated with bacterial contamination of reusable suction tips in patients undergoing total joint arthroplasty under standard ultraclean operating room conditions.

Materials and methods

This study was reviewed and approved by the institutional review board (IRB) of our affiliated institutions. It was carried out according to the Declaration of Helsinki.

A prospective study of consecutive patients who underwent primary total joint arthroplasty (TJA) between December 2021 and March 2022 was performed. All TJAs in this study were performed by the chief physician at each joint division in one institution. These patients were followed up for a minimum of three months after surgery to examine for clinical signs of early superficial or deep infection described by Tsukayama et al.[27].

Inclusion criteria were: (1) any age with written informed consent given to participate in the study; (2) treatment with total hip arthroplasty or hemiarthroplasty, total knee arthroplasty, or total shoulder or reverse total shoulder arthroplasty; (3) and clinical and radiological data available preoperatively, immediate postoperatively, and at one and three months.

Exclusion criteria were: (1) follow-up loss including expired or no appropriate clinical or radiologic follow-up; (2) or clinical failure to perform culture testing with appropriate specimens.

Study design and patients' group

Between December 2021 and March 2022, a total of 142 patients were admitted to our hospital for total joint arthroplasty.

After inpatient admission, all patients underwent preoperative shaving of the surgical site with hair removal cream containing thioglycolic acid and a disposable razor the day before surgery. To disinfect the surgical site, the local skin was washed three times with an antiseptic solution (povidone-iodine 7.5% containing solution containing ammonium nonoxynol-4 sulfate, nonoxynol-9, and sodium hydroxide) for at least five minutes. Standard preoperative skin antisepsis of the patient's extremities prior to initiation of surgery was performed using an antiseptic solution (povidone-iodine 10.0%). Patients received single-shot preoperative antibiotic prophylaxis (cefazolin 1g or flomoxef 1g intravenously within 60 minutes before skin incision), as well as intraoperative antibiotics if the surgery lasted more than three hours [22]. In the case of cephalosporin hypersensitivity, 1g of vancomycin or 400mg ciprofloxacin was administered intravenously 120 minutes before skin incision [5; 11]. Postoperative IV antibiotics was given for 24 hours after TJA [30]. Wound drainage was routinely used in the patient population.

Sterile draping was performed following a routine protocol, with a two-layer sterile covering towel (KM healthcare Corp., Guri-si, Gyeonggi-do, Republic of Korea). Spacesuit technology was routinely used to maintain a clean air operating environment (Flyte Personal Protection Systems (Stryker Corp., Kalamazoo, MI, USA) [17]. A High-efficiency particulate absorbing (HEPA) filter with filtration efficiency of more than 99.97% was routinely used along with laminar air flow [3; 4; 13; 25]. The operating room

temperature was set to 21 degrees Celsius, and a continuous suction device with a pressure of 200mmHg or higher was routinely used with reusable suction tips [10; 29].

Two reusable suction tips (Jarit Suction Tip Fraizer No 12) that were treated with the same sterilization protocol were prepared (Fig. 1). One tip was incubated before surgery and excluded from use during surgery; the other suction tip was used for surgery and cultured after the surgery. The reusable suction tips were plated on MacConkey agar plate for Gram-negative bacteria and on blood agar plate for bacteria that are more difficult to grow, and in the liquid media for other bacteria, yeast, algae and animal cells (Fig. 2, Supplementary Information). After each surgery, all samples were sent to a microbiological institute where they were incubated for at least 14 days. In case of contamination, bacterial species were identified, and resistograms were established.

Statistical analysis

A continuous sampling technique was used to select all subjects who met the inclusion criteria for the duration of the study.

Pearson's chi-square test was used to compare the differences in the categorical demographic variables. The dependent samples Student t-test or Mann–Whitney U test were used to compare continuous variables according to normality or sample size. Pearson's correlation coefficient was used to determine the strength of linear correlation.

All patient records were anonymized, saved as a Microsoft Excel file, and managed as a supplementary document. The statistical analysis was performed using the SPSS 25 software (SPSS Inc., Chicago, IL, USA).

Results

Among 142 patients, four cases were excluded (three cases lacking clinical data, and in one case, no culture testing had been performed). Of the remaining 138 cases, patients experienced a mean delay of 2.1 days from initial admission to surgery and were operated on under general anesthesia. Basic patient demographics are given in Table 1.

Table 1
Patients' demographics and outcome

Patients M/F	THA	BPHA	TKA, unilateral	TKA, bilateral	rTSA or TSA	Total
	24	22	63	25	4	138
	14/10	11/11	12/51	1/24	1/3	39/99
Age	57.9 ± 12.4	76.0 ± 13.1	70.7 ± 7.9	73.2 ± 6.2	74.8 ± 6.9	69.9 ± 11.1
BMI	24.6 ± 2.9	22.5 ± 3.9	27.1 ± 3.8	27.4 ± 4.3	22.7 ± 1.5	25.9 ± 4.1
Side (R/L)	13/11	14/8	25/38	N/A	1/3	N/A
Diagnosis	ONFH 16 OA 6 Femur neck fracture 2	Proximal femur fracture 22	OA 60 ON 2 RA 1	OA 25	OA 3 Proximal humerus fracture 1	N/A
Surgery duration (min)	133.5 ± 19.6	114.9 ± 30.9	193.1 ± 27.4	323.6 ± 47.9	246.3 ± 22.5	195.5 ± 75.9
Preop culture (+)	2	-	5	-	-	7
Postop culture (+)	-	-	1 (186 min)	1 (280min)	-	2

The preoperative culture test showed positive culture findings in seven patients (5.1%; Table 1, Fig. 3). *Staphylococcus hominis* was detected in two patients. In addition, *Staphylococcus cohnii*, *Kocuria* species, *Roseomonas gilardii*, *Bacillus* species, and *Burkholderia ambifaria* were detected in reusable suction tip cultures.

The suction tip investigation at the end of surgery showed bacterial contamination in only two patients (1.4%) (Table 1, Fig. 3). In two patients, *Staphylococcus warneri* and *Saccharopolyspora hordei* were detected.

Among the patients who were positive in the preoperative evaluation, none of them were positive in postoperative culture findings. None of the patients with positive postoperative culture had an operation time of less than three hours (Table 1, Fig. 4). There was a very weak positive correlation ($R^2 = 0.060$) was found between the duration of surgery and positive microbial findings of reusable suction tip (Fig. 4).

At the routine follow-ups one and three months postoperative, no patient showed any clinical or laboratory evidence of periprosthetic joint infection (PJI), and there were no wound-healing complications at outpatient follow-up examination.

Discussion

In this prospective cohort study evaluating the microbial contamination of reusable suction tips during primary total joint arthroplasty (TJA), we identified a preoperative culture positivity rate of 5.1% and a postoperative rate of 1.4%. Intriguingly, none of the patients with preoperative contamination showed positive cultures postoperatively, whereas all postoperative positive cultures were observed exclusively in procedures lasting longer than three hours. These findings highlight the nuanced dynamics between surgical instrument sterility, intraoperative conditions, and operative duration.

To the best of our knowledge, no researcher has studied reusable suction tips or performed preoperative cultures. Other researchers who used disposable suction tips have reported postoperative culture positive rates ranging from 7.8% to 54% [6–8; 12]. Other authors have reported culture positive rates from 37% to 54% but without indicating whether the suction tips were disposable or reusable, and the technology was insufficient for other devices and conditions in the operating room [9; 24].

The primary cause of preoperative contamination can be attributed to the structural complexity of reusable suction instruments combined with potential setup-phase cross-contamination. Reusable suction devices for clearing the surgical field are among the most commonly used surgical tools because a clear view of the surgical field is essential. However, instrument surgical asepsis is not easy. Reusable suction tips feature a narrow, curved tubular lumen that poses inherent challenges to thorough mechanical washing and steam sterilization by the Central Sterile Services Department (CSSD). In the case of the reusable suction tips, sterilization is more difficult because the narrow tubular structure is curved. Microscopic organic debris or resistant biofilms may persist within the internal lumen despite standard reprocessing protocols. Furthermore, the microorganisms identified preoperatively—such as *Staphylococcus hominis*, *Staphylococcus cohnii*, and *Bacillus species*—are predominant skin commensals and ubiquitous environmental organisms. This suggests that micro-level contamination could also occur during the opening of sterile packaging and line assembly prior to skin incision.

The elimination of pre-existing bacterial contamination during surgery can be explained by a continuous 'wash-out' phenomenon alongside the inhibitory action of prophylactic antibiotics. Throughout TJA, the continuous passage of high-pressure suction (≥ 200 mmHg) and high-volume saline irrigation physically flushes and dilutes the initial bacterial load inside the tip. Concurrently, systemic prophylactic antibiotics administered preoperatively result in antibiotic-laden blood passing through the lumen, further suppressing microbial viability.

However, this protective wash-out effect has a temporal threshold. Postoperative microbial contamination was detected only in cases with an operative duration exceeding three hours (186 and 280 minutes). Prolonged environmental exposure and surgical field manipulation appear to surpass the

intraoperative dilution capacity, leading to the re-accumulation of airborne and field contaminants over extended surgical times.

Different researchers have reported on different operating room conditions such as the varying use of high-efficiency particulate absorption (HEPA) filters, positive laminar air flow, and continuous suction pressure, and these factors could have influenced the different study. In this study, we used an enhanced heating, ventilation, and air conditioning (HVAC) system with a HEPA filter with a filtration efficiency of 99.981% and laminar air flow. It can be assumed that this operating room environment may have lowered the overall preoperative and postoperative culture positivity rates.

Contrary to expectations, the number of positive patients in the preoperative culture test was higher than the number of positive patients in the postoperative culture test. The preoperative culture test was positive in seven patients, postoperative cultures were positive in only two, and among the patients who were positive before surgery, none of them were positive after surgery. We consider that we did not encounter or introduce pathogens during surgery that could cause infection because the operations were performed under well-designed HVAC system and continuous suction with high pressure. In addition, the patients with postoperative culture positive findings had relatively long surgery times of 186 minutes and 280 minutes.

Based on these findings, several key clinical recommendations are proposed to minimize contamination and infection risks during joint arthroplasty. Foremost, procedural efficiency should be optimized to ensure that primary procedures are completed within three hours, as prolonged operative time significantly elevates the risk of instrument contamination. Alongside strict time management, the inherent reprocessing challenges of narrow-tubular reusable tips must be thoroughly addressed. Stringent lumen-specific cleaning protocols must be implemented during the sterilization process; moreover, transitioning to single-use disposable suction tips should be strongly considered to eliminate baseline sterilization failure risks. Ultimately, these procedural and instrumental safeguards must be reinforced by an optimized operating room environment, utilizing enhanced HVAC systems equipped with HEPA filtration and laminar airflow to maintain clean air circulation and prevent airborne bacterial settling over the surgical field.

There are some limitations of this study. First, although this is a prospective study and an appropriate sample size was secured, it would have been possible to generalize the frequency of postoperative positive findings according to operation time if a large-scale study had been conducted with a larger sample. Second, two reusable suction tips were prepared for each subject, with one culture tested before the surgery and one after. This study was designed in consideration of the effect on surgery of using a suction tip that has been cultured is used for surgery. However, even though the reusable suction tips were treated under same sterility protocol at this hospital, the degree of sterilization of the suction tip could have been different, and this could have affected the experimental results. Third, in the same operating room where HVAC has been equipped, there is a limit to that it would have been more meaningful if we had set research to compare disposable and reusable suction tips.

Conclusion

In conclusion, the presence of positive bacterial cultures both preoperatively and postoperatively demonstrates that reusable suction tips serve as a potential source of infection in joint arthroplasty. Notably, postoperative contamination is closely associated with prolonged operative duration exceeding three hours. To effectively mitigate these infection risks, strict surgical time management and rigorous instrument sterilization protocols are imperative. Furthermore, considering the inherent challenges of reprocessing narrow-tubular instruments, transitioning to single-use disposable suction tips and maintaining an optimized operating room environment with advanced heating, ventilation, and air conditioning (HVAC) systems are strongly recommended.

Declarations

Author Contribution

J-H Song, HS Koh and JW Moon have made substantial contributions to the conception, design, and drafting of the manuscript. J Jeong and HW Park participated in the design of the study. S-Y Kim and HS Jung analyzed the data and wrote the manuscript. CJ Park and S Oh edited and revised the manuscript. All authors have read and approved the final version of the manuscript.

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Figures

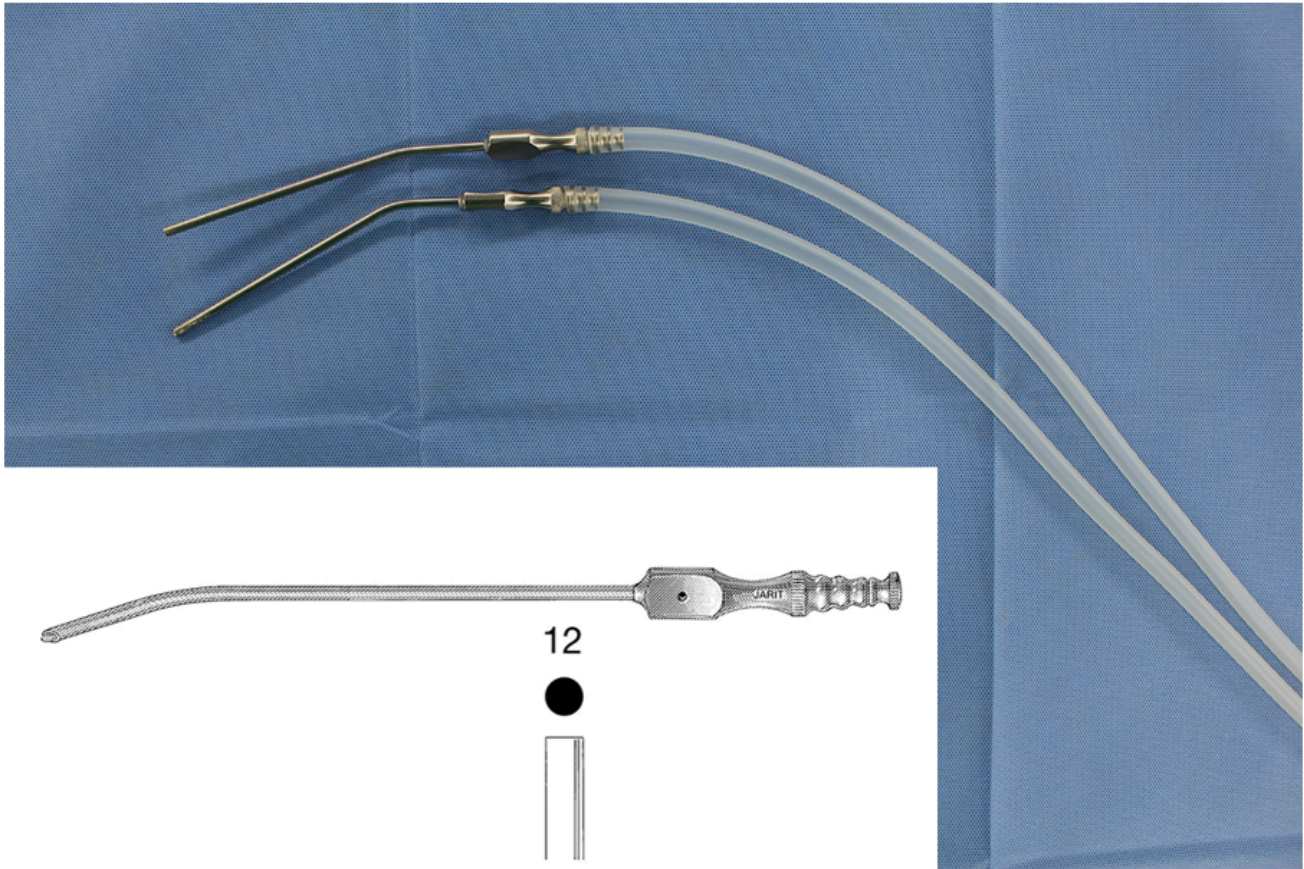


Figure 1

Jarit Suction Tip Fraizer No 12



Figure 2

MacConkey agar plate, blood agar plate, and liquid media

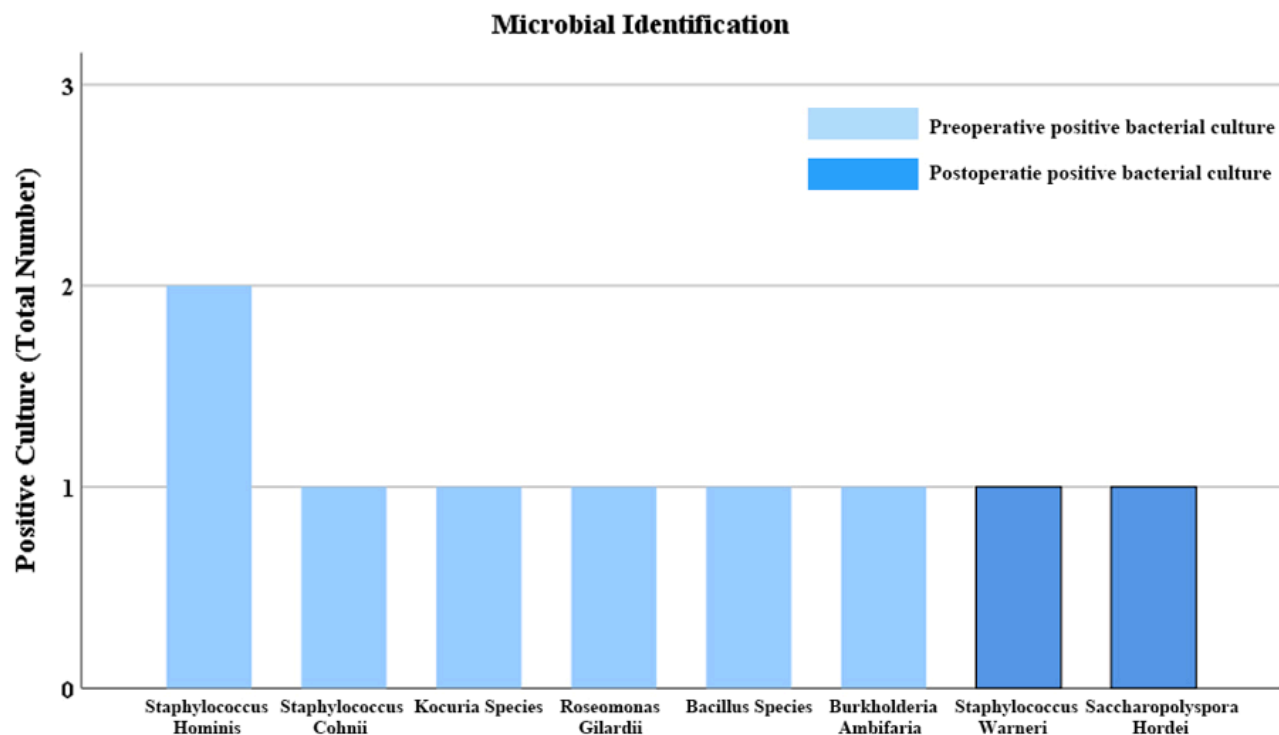


Figure 3

Microbial identification

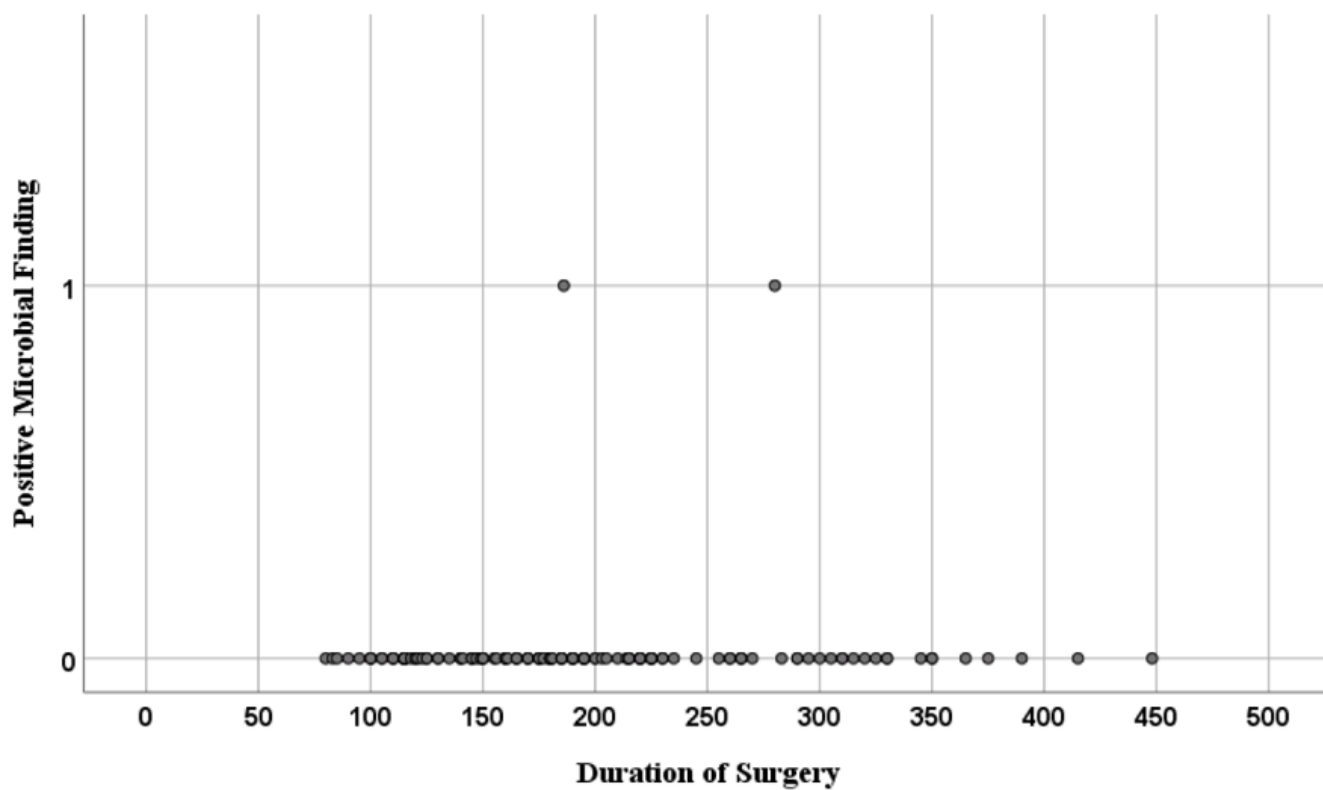


Figure 4

Correlation between the advanced duration of surgery and positive microbial findings of reusable suction tips ($R^2=0.060$)

Supplementary Files

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