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Research Article

AN IN VITRO EVALUATION OF CAPILLARY RISE AND BACTERIAL RESISTANCE IN SURGICAL SUTURES

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ABSTRACT

Background: There has been a constant effort to provide information on textile behaviour of suture materials in order to assist surgeons in their selection of adequate sutures for specific surgical applications. The aim of this study was to provide information on capillary behaviour and bacterial resistance of suture materials that assist practitioners and surgeons to get a better understanding of suture applications. A comparative experimental study between two different manufacturers was carried out during this work.

Materials & Methods: Commercially available surgical sutures from two different manufacturers i.e. one from India (S) and another from abroad (J) were used, both consisting of monofilament and braided configuration. Effect of coating on the basis of capillary rise and bacterial resistance on various surgical sutures was analysed. Preparation of Simulated Body Fluid (SBF) was done, Capillary tests were done in a specific environmental condition and standard method, Optical density measurement was also done and specific bacterial culture was used.

Results: Obtained results show that, coating seems to contribute a major role towards bacterial resistance and capillary rise in non-absorbable braided sutures and is found to be higher than absorbable ones depending on constituent fibre properties.

Conclusion: This study clearly indicates that, apart from physical and chemical configuration of suture, coating is a major factor which contributes to bacterial attachment.

INTRODUCTION

Suture materials when implanted in wounds are known to cause an adverse reaction on the condition of local tissues, hence increasing the sensitivity to infection [1-3]. "Surgical sutures potentiate infection when necrotic or de-vascularised tissue, hematoma or dead spaces caused by tissue damage or poor surgical technique are present" [4]. The nature of suture material implanted influences the ability of the sutured tissue to withstand infection [5].The variations in the sutures' capillarity and fluid absorption properties determine bacterial transport along the suture filaments. The purpose of this study was to investigate the capillarity and bacterial resistance behaviour of various surgical sutures.

MATERIALS

Commercially available surgical sutures from two different manufacturers i.e. one from India (S) and another from abroad (J) were used. From each of the manufacturers, 2-0 non-absorbable sutures and 2-0 absorbable sutures were considered, both consisting of monofilament and braided configuration.

Non-absorbable monofilament J and S sutures (abbreviated NMJ and NMS respectively) composed of nylon, non-absorbable braided J and S sutures (abbreviated NBJ and NBS respectively) composed of polyester, absorbable monofilament S sutures (abbreviated AMS) composed of poliglecaprone, and absorbable braided J and S sutures (abbreviated ABJ and ABS respectively) composed of polyglactin 910 were evaluated in this study. A detailed description of suture characteristics tested in the study is mentioned in Table 1.

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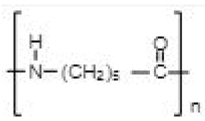
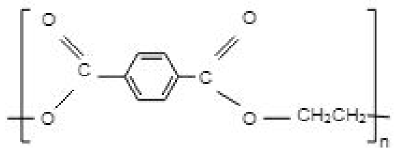
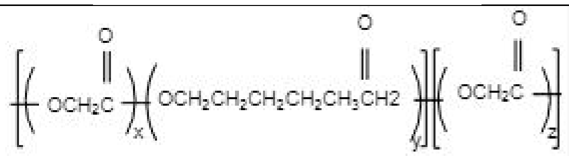
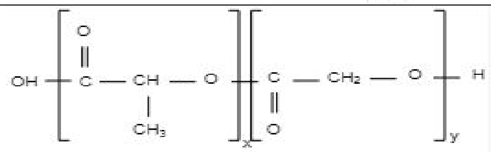
Table 1 Characteristics of sutures tested in the study

Type	Code	Physical configuration	Composition	Chemical structure	Diameter (mm)
2-0 Non-absorbable	NMJ NMS	Monofilament	Nylon		0.360 0.386
	NBJ NBS	Braided	Polyester		0.389 0.810
2-0 Absorbable	AMS	Monofilament	Poliglecaprone		0.294
	ABJ ABS	Braided	Polyglactin 910		0.447 0.549

METHODS

Preparation of Simulated Body Fluid (SBF)

Body fluid having ion concentrations similar to human blood plasma is simulated to assess capillary behaviour of sutures and is buffered at pH 7.40 with tris (hydroxymethyl) aminomethane and hydrochloric acid at 36.5°C [6].

1. All the beakers and wares are washed with 1N-HCl solution, neutral detergent, and ion -exchanged and distilled water, and then dried.
2. 500 ml of ion-exchanged and distilled water is put into one litre polyethylene beaker.
3. All the reagents, as shown in Table 2 are dissolved in water one after the other and the temperature of the solution is adjusted at 36.5℃ with a water bath, and pH of the solution is adjusted to 7.40 by stirring the solution and titrating with 1N-HCl solution.
4. The total volume of the solution is then adjusted to one litre by adding ion-exchanged and distilled water.

Table 2 Reagents for preparing SBF (pH 7.4, 1L)

Order	Reagent	Amount
1	NaCl	7.996 g
2	$NaHCO_3$	0.350 g
3	KCl	0.224 g
4	$K_2HPO_4.3H_2O$	0.228 g
5	$MgCl_2.6H_2O$	0.305 g
6	1M-HCl	40 ml
7	$CaCl_2$	0.278 g
8	Na_2SO_4	0.071 g
9	$(CH_2OH)_3CNH_2$	6.057 g

Capillary test

This test is carried out at an atmospheric condition of 65 % ± 2 % relative humidity and 27 ºC ± 2 ºC temperature for all sutures. The standard method DIN 53924 was used to assess capillary behaviour of sutures. The instrument is made up of a metal stand in which a steel ruler is attached on the right side of the apparatus to record the height of Simulated Body Fluid (SBF) travelled along the sutures.

A sample holder is fixed on the top of the metal fixed clamp holder in which a suture length of 20cm was hung vertically and the other end tied with a weight of 0.015g/tex. Once the sutures were in contact with the SBF, height was recorded for every 5 min, 10 min, 15 min and 20 min respectively. A magnifying lens was used to observe the capillary rise along the length of suture.

Bacteria culture

The bacteria culture consists of a liquid media prepared by adding 1.3 g nutrient broth in 100 ml distilled water in a flask. This liquid media is kept for 4hrs in the autoclave maintained at temperature120°C. 2 ml active culture of Pseudomonas aeruginosa (grown at 35°C) is transferred in the flask containing liquid media and incubated (Innova 42, Eppendorf, USA) for 18 hrs at 35°C give a stock solution of 10^9 bacteria per millimetre [7].

Optical density measurement

From this stock solution, a series of 1:10 dilutions were prepared for the various experiment. Each suture, 3 cm in length is placed in two tubes containing stock solution. One of which is meant to determine number of bacteria attached initially to suture surface and, the other one, is agitated in Innova 42, Eppendorf (USA) incubation shaker at 50 rpm for 24 hours. The sutures are, then, picked up with fine forceps and the adhered bacteria are washed by immersion of the sutures in distilled water (10 ml). The optical density of the bacteria concentration in respective distilled water is measured by the spectrophotometer (Lambda 365, PerkinElmer) at 600 nm, which gives an estimation of bacterial resistance to sutures.

RESULTS AND DISCUSSION

Capillary rise

Capillary rise in all braided sutures is measured for every 5min, 10min, 15min and 20 min. The results of wicking behaviour are given in *Table 3*and *Figure 1.*

From *Figure 1*, it is observed that among each manufacturer, non-absorbable braided (polyester) sutures show maximum capillary rise as compared to that of absorbable braided (polyglactin 910) sutures. This can be explained on the basis of absorption characteristics of suture material. Suture threads composed of polyester (NBJ and NBS), being hydrophobic in nature, allow the fluid to flow through the channels along the fibres rather than absorbing it; unlike polyglactin 910 absorbable braided (ABJ and ABS) sutures.

It is observed that ABJ suture shows least fluid uptake, however, when uncoated, shows capillary rise to an extent. This can be due to the antibacterial triclosan coating on commercial ABJ sutures done with a view to minimise contamination by microorganisms, when implanted. The braided sutures due to high capillary action have been found to absorb more fluid harbouring pathogens and may also lead to body fluid breaking out of the wound [9, 10]. Previous studies on bacterial transport also reported the risk for wound-healing disturbances via capillaries [8, 12] and in order to reduce capillarity, attempts have been made of coating the sutures while manufacturing. Thus, ABJ suture being braided as well as absorbable in nature is coated in order to completely block (or reduce) the interstitial spaces of suture. Other than ABJ, all coated sutures are found to exhibit a certain level of capillary rise. This capillary behaviour of NBJ, NBS, and ABS sutures can be explained by the possibility that only the outermost surface of these sutures is coated against the bacterial action; paving the way for fluid to flow through channels. Lilly and colleagues attempted to reduce capillarity by coating the braided sutures, however, failed to inhibit bacterial growth on sutures [13], attributed to the way treatment was done i.e. peripheral coating [12]. The capillary rise trend followed by braided sutures for every 5min, 10min, 15 min and 20 min is shown *Figure1*.

Table 3 Capillary rise in braided sutures

Sample code	Capillary rise (cm) (n=5)			
	5 min	10 min	15 min	20 min
NBJ	2.85	3.46	3.96	4.50
NBS	5.15	6.53	8.35	9.34
ABJ	0	0	0	0.80
ABJ (uncoated)	1.20	2.90	3.45	4.00
ABS	4.14	5.23	6.08	6.86

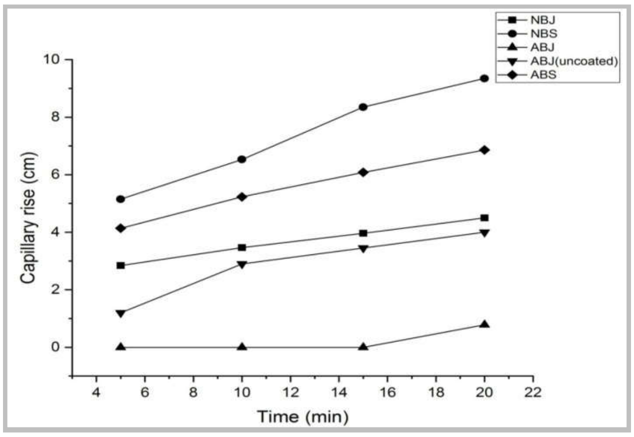


Figure 1 Capillary rise in different sutures at various intervals of time

Bacterial Resistance

The interaction between sample sutures and bacteria is evaluated quantitatively by optical density measurement and is expressed, in terms of bacterial reduction (or efficiency) % i.e. ability of suture material to resist infection at implantation site (due to bacterial resistance).

The bacterial reduction% is calculated using the formula as mentioned in following equation and the corresponding results are given in *Table 4*.

$$\text{Bacterial reduction\%} = \left(\frac{\text{O.D.}-\text{O.D.}'}{\text{O.D.}}\right) \times 100$$

where, O.D.= Optical density of solution at zero point of time and O.D.'= Optical density of solution after 24 hours

Table 4 Bacterial reduction% in sutures

Sample code	Bacterial reduction% (n=5)
NBJ	74.40
NBS	51.24
ABJ	78.75
ABJ (uncoated)	50.00
ABS	77.09
NMJ	72.05
NMS	57.57
AMS	69.15

It is observed that ABJ (polyglactin 910) suture shows highest efficiency towards bacterial resistance, however when uncoated, exhibit least efficiency among all the coated sutures. This is a clear indication that antibacterial coating on ABJ suture exhibits bactericidal activity, significantly, against cultured bacteria.

From *Table 3*, it is found that bacteria are resisted differently by various suture materials under the same experimental conditions. A previous study on surgical sutures reported the variation in bacterial adherence as a function of the physical configuration and chemical structure of the suture material [14]. However, the observed results in this investigation seem to be irrespective of the physical configuration and chemical structure of the suture materials. It is observed that all braided sutures of both the manufacturers (ABJ, ABS, and NBJ) except NBS exhibit high efficiency towards bacterial resistance as compared to respective monofilaments (AMS, NMS, and NMJ). As configuration of braided sutures act as a tract for bacteria, anti-bacterial (or finishing) treatment might have been done on these sutures, hence showing high efficiency towards bacterial resistance.

It is also observed that, sutures of Indian manufacturer exhibit less efficiency towards bacterial resistance as compared to the respective abroad manufactured sutures. This bacterial reduction% variation in Indian and abroad manufactured sutures and exceptional behaviour of NBS can be attributed to the anti-bacterial (or finishing) characteristics i.e. composition and thickness with which sutures were treated.

CONCLUSION

In this research, the capillary rise behaviour and bacterial resistance for absorbable and non-absorbable surgical sutures were studied. Despite of coating, non-absorbable braided sutures offer reliable capillary behavior due to hydrophobic nature of constituent suture material. Also, our results show that bacterial resistance differs in surgical sutures depending on the type, mechanism, and characteristics of coating in suture materials. This data clearly indicates that, apart from physical and chemical configuration of suture, coating is a major factor which contributes to bacterial attachment [9].

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