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Full Length Research Paper

Comparison of physical properties of sutures in medical liquids

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In this study, some physical properties of natural and synthetic absorbable sutures are compared. Normal catgut and poly (glycolide-co-caprolactone) sutures were used due to their monofilament structures. Advantages and disadvantages of these sutures were experimentally observed. Knotted and unknotted suture samples were individually put into different liquids such as; medical solutions, distilled water and blood having different amounts of erythrocyte, thrombocyte and plasma. Samples were divided into two groups and each group was kept in different temperatures during two weeks. Tensile strength, tensile strain and mass loss were determined once in each two days.

Key words: Absorbable sutures, catgut, poly (glycolide-co-caprolactone), knot strength, tensile strain, tensile strength, mass loss.

INTRODUCTION

Medical textiles are the most important sub-groups of technical textiles. Because they contain personal health-care and hygienic products. The rate of growth is related with developments and innovations in both textile technology and medical procedures (Rigby and Anand 2000).It is known that history of medical textiles is very old. Sutures, which were defined as implanted textile materials, were firstly used in 2000 B.C (Yükseloğlu and Canoğlu, 2003). Flax was used in wound dresses in Egypt at 2nd century B.C (Gürdal, 1997).

Fibres, yarns and fabrics are also used in different applications, except clothing and furnishing. This was clearly understood after technical textiles had considerably attracted attention. Technical textiles have already had an increasing market share (Byrne, 2000). The usage of fibres and fabrics in important applications of medical and surgical scope started with usage of sutures before more than 4000 years. Today, they are used in many different products from surgical clothes to wound dresses and from artificial organs to vascular grafts (Cireli et al., 2007).

Researches on fibres and fabric-forming techniques have caused to develop medical and surgical textiles. These developments are obtained by fibre manufacturers because fibre type is chosen according to requirements such as; absorbency, tenacity, flexibility, softness or biodegradability (Shamash, 1989). In medical applications, complex technical textiles with high standards are needed. Developments have increased with parallel to advancement in textile technology and medical textile processes. These products range from sutures and the smallest finger bandage to complex composites used for bone transplantation, vascular prosthesis and heart valves (Uçar, 2006).

Textile materials, which are designed to meet particular needs, are suitable for any medical and surgical application where combination of strength, flexibility, and sometimes moisture and air permeability are required. These materials are monofilament and multifilament yarns, woven, knitted, and nonwoven fabrics, and composite structures. The numbers of applications are huge and diverse, ranging from a single thread suture to complex composite structures for bone replacement, and from the simple cleaning wipe to advanced barrier fabrics used in operating rooms. These applications can be categorised into four separate and specialised areas as follows:

Non-implantable materials: Wound dressings, bandages, plasters, etc.

Extracorporeal devices: Artificial kidney, liver and lungs.

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Implantable materials: Sutures, vascular grafts, artificial ligaments, artificial joints, etc.

Healthcare/hygienic products: Bedding, clothing, surgical gowns, cloths, wipes, etc. (Rigby and Anand, 2000).

Sutures are natural or synthetic surgical materials used to join tissues or blood arteries without any mechanical support. They have enough strength to resist tensile stress until wound heals (Ulcay and Karaca, 1993). Sutures are monofilament or multifilament threads which are categorised as biodegradable or non-biodegradable. Biodegradable sutures are basically used for internal wound closures. External wounds are generally closed with non-biodegradable sutures and these sutures are removed when the healing is started (Rigby and Anand 2000).

It was studied by Gülgönül (1991) how suture performance was affected from material type and production method. Silk sutures, which had same number and were produced from different manufacturers, were tested. It was measured that elastic properties of these sutures were considerably different from each other. It was reported that raw material quality and production technology of sutures had an important effect on suture elasticity. Production and characterisation of biodegradable copolymers and fibres were investigated by Köktürk (1996). If sutures were produced from same raw material by different manufacturing methods, mechanical properties of sutures changed.

Monofilament polypropylene suture was produced by Gürdal (1997). Mechanical and physical properties of these sutures were classified. Tissue compatibility of these polypropylene monofilament sutures were studied on animals *in vivo.* It was studied by Oran (1999) that collagen was extracted from sheep intestine by enzymatic hydrolysis method. It was noted that collagen could be used in biomaterials because catgut was produced from sheep intestine and biological structure of intestine was compatible with tissue.

It was analysed by Bayraktar (1999) that how mechanical properties were affected from structural properties. Monofilament sutures, which were produced from silk, polyamide 6, polyester or polypropylene sutures, had low mechanical resistance than cross-braided sutures produced from same raw materials.

Tensile strengths of simple catgut and chrome catgut sutures were compared by Gemci and Ulcay (2004). Sutures having different diameters had different resistance to tensile stress. It was reported that suture diameter had a significant effect on tensile strengths of sutures.

METHODOLOGY

Materials

Tekmon suture

It is synthetic, absorbable, monofilament and sterile suture. Tekmon suture is made from poly (glycolide-co-caprolactone copolymers. It does not cause to antigenic and pyrogenic problems but tissue reactions can occur during absorption of suture.

Empirical chemical formula: $(\text{-O-CH2-CH2-OCH2-CO-})_n$
USP (United States Pharmacopoeia): 5/0
EP (European Pharmacopoeia): 1
Colour: Colourless
Coating: Uncoated
Tissue supporting period: More than 65% in one week, more than 30% in two weeks
Usage fields: Dermis / Sub-cuticular, ligation, peritoneum, stomach, intestine, colons, bladder, uterus, plastic surgery.

Simple catgut

It is natural, absorbable, monofilament and sterile suture.
USP (United States Pharmacopoeia): 2/0
EP (European Pharmacopoeia): 2.5
Colour: Colourless
Coating: Uncoated
Tissue supporting period: 4 to 5 days

Medical liquids

Full blood: It is pure blood drawn directly from a healthy female donor. 63 ml anticoagulant is added into 450 ml blood without applying another process. Hematocrit level is determined as 36 to 37% on average. It consists of 250 ml plasma and 200 ml erythrocyte. Thrombocytes lose their functions when blood sample is stored at +4°C (Celkan, 2004).

Erythrocyte suspension: Erythrocyte suspension is obtained if three-quarters of plasma is removed from blood. 60 to 90 ml plasma, which is equal to the amount of one-quarters of plasma in erythrocyte, is enough for living metabolism and anti-coagulating of erythrocyte (Celkan, 2004).

Thrombocyte (platelet) suspension: Blood sample was centrifugated during 8 h. Thereby thrombocytes were separated from blood cells. They are shaken continuously at 20 to 24°C. Thrombocytes lose 20 to 25% of their vitality after 5 days (Celkan, 2004).

Blood plasma: Blood plasma was obtained by centrifugating plasmapheresis of blood. It contains all coagulation elements like globulin and albumin (Celkan, 2004).

Isotonic NaCl solution: Sodium chloride solution is one of the extracellular liquids for human body. Pressures of some body liquids are equal to isotonic sodium chloride solution with a concentration of 0.9%. NaCl solution is used to supply electrolyte requirement of body (Celkan, 2004).

Dextrose solution: It is a steril and apyrogen solution containing pure glucose. Dextrose solutions are accurately compatible with human body if they have concentration of 30%. It is an extra-cellular liquid and used to meet liquid loss of body.

Distilled water: Distillation is defined as purifying of two or more materials by decomposing them with heating or cooling. Distilled water is obtained after being condensed of vaporised water.

Equipments

1) Refrigerator: Sutures in blood and blood components are kept in it at

+4°C.
2) Precision balance: Samples are periodically weighted.
3) Tensile strength testing device: Tensile strengths of sutures waited in blood and blood components are tested.

Methods

Tests were carried out according to ASTM D3217-07 standards. Synthetic and natural sutures were cut at length of 6 cm. On the other hand, sutures were knotted to test knot strength. 294 knotted and knotless samples were prepared for each suture type. There were totally 1176 knotless and knotless samples. These samples were separately put into tubes containing seven different medical liquids. They were kept in two different temperatures such as: +21 and +4°C. Because medical treatments were operated at +21°C and medical liquids were prepared at +4°C according to Biomedical Laboratory of Stuttgart Textile Fibre and Research Institute.

RESULTS

Tensile strengths, tensile strains and weight losses of these samples were tested at each two days. Changes occurred in different medical liquids were illustrated in following figures (Figures 1 and 2).

Strengths of Tekmon sutures were higher than that of catgut sutures. However catgut sutures were extremely affected from temperature increase. There were no considerable changes on tensile strengths of tekmon sutures, even at higher temperature (Figures 3 and 4).

Catgut samples were seriously deformed by blood. Tensile strengths of catgut sutures were higher at lower temperature. Strengths of unknotted tekmon sutures did not change, even in higher temperature. Tensile strengths of tekmons were slightly decreased at +4°C (Figures 5 and 6).

Erythrocyte suspension caused important deformations on both unknotted and knotted sutures. Tekmon sutures saved their strengths in erythrocyte suspension (Figures 7 and 8).

Thrombocyte suspension decreased strengths of all sutures. Catgut sutures had lower strengths at higher temperatures (Figures 9 and 10).

Unknotted catguts were the most effected samples from plasma suspension (Figures 11 and 12).

Sutures were more durable at higher temperature by keeping them at 21°C. Decrease in tensile strength was higher at 4°C in isotonic solution for knotted and unknotted catgut (Figures 13 and 14).

Unknotted and knotted tekmon sutures did not affected from dextrose at both low and high temperature. But catguts were the most deformed samples again (Figures 15 and 16).

Keeping sutures in distilled water made catgut sutures elongate seriously. The effect of distilled water on tekmon sutures was negligible (Figures 17 and 18).

Behaviours of sutures in blood were nearly the same. But catgut samples were deformed at +21°C (Figures 19 and 20).

At the temperature of 21°C, unknotted and knotted

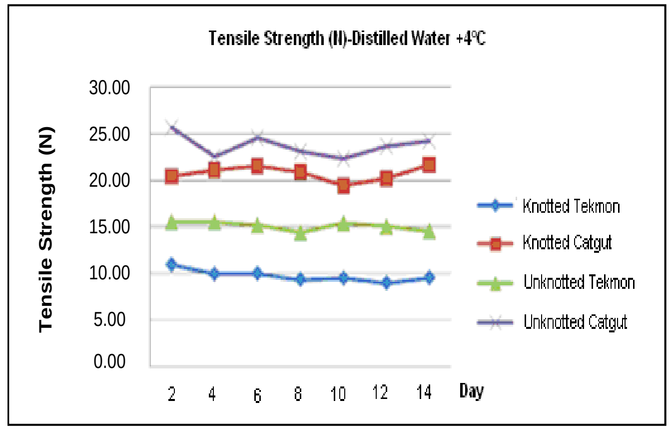

Figure 1. Effects of distilled water at +4°C on tensile strengths of sutures.

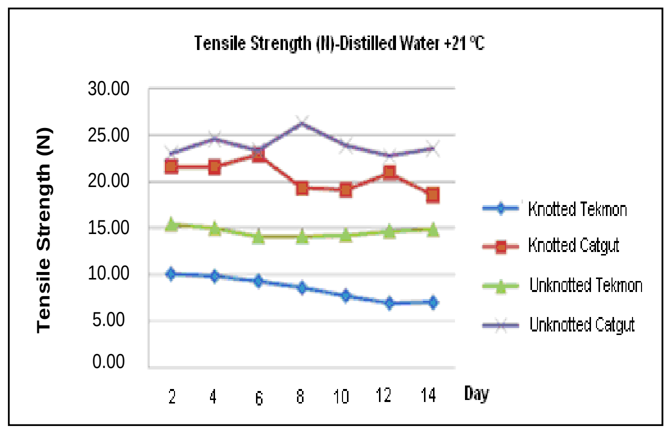

Figure 2. Effects of distilled water at +21°C on tensile strengths of sutures.

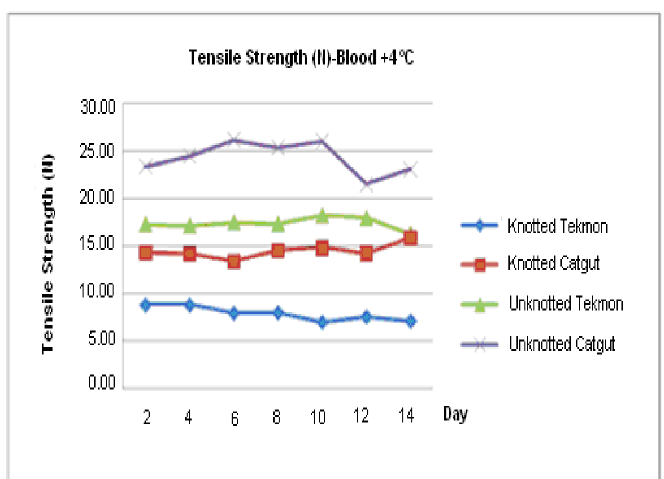

Figure 3. Effects of blood at +4°C on tensile strengths of sutures.

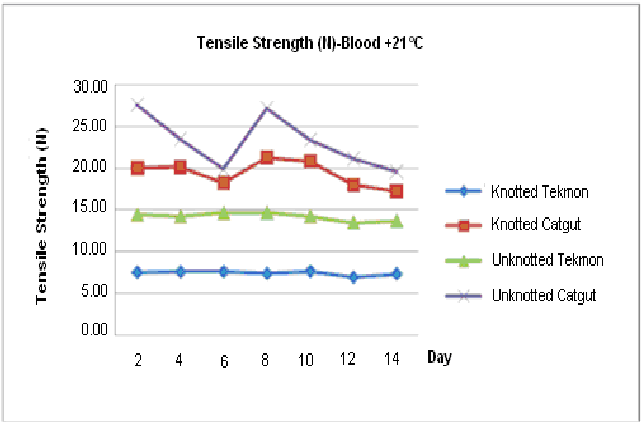

Figure 4. Effects of blood at +21°C on tensile strengths of sutures.

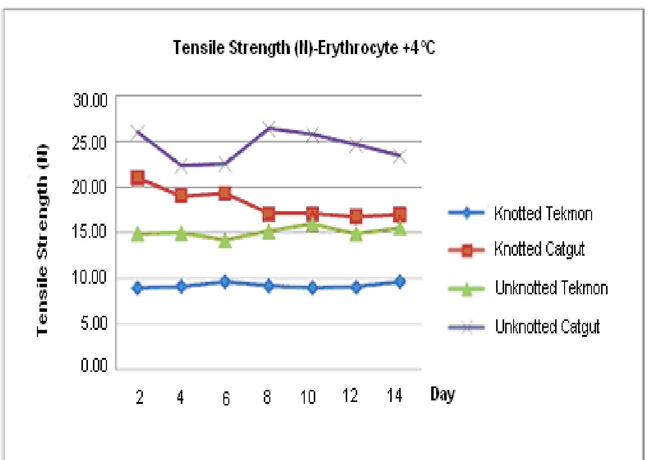

Figure 5. Effects of erythrocyte suspension at +4°C on tensile strengths of sutures.

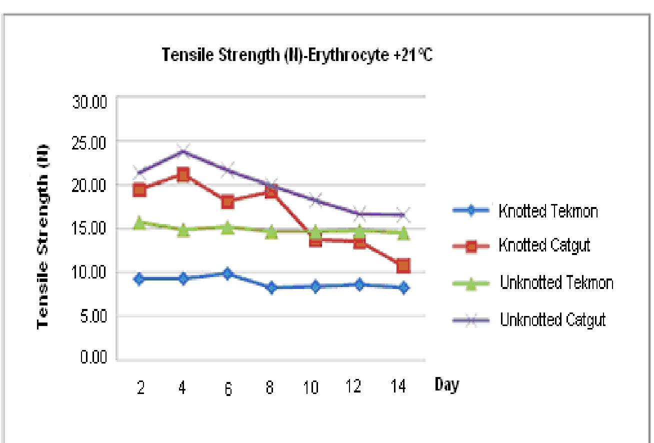

Figure 6. Effects of erythrocyte suspension at +21°C on tensile strengths of sutures.

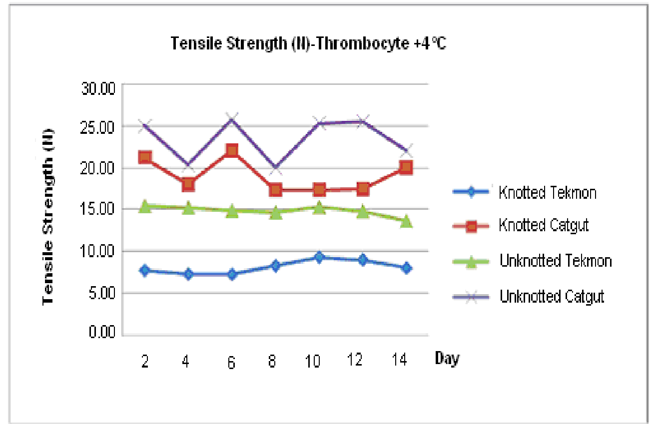

Figure 7. Effects of thrombocyte suspension at +4°C on tensile strengths of sutures.

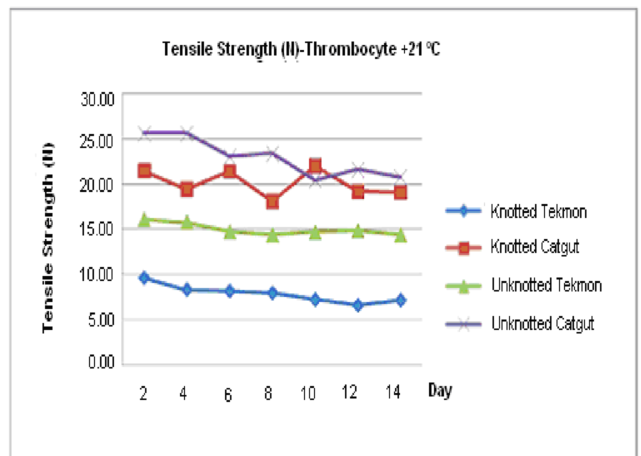

Figure 8. Effects of thrombocyte suspension at +21°C on tensile strengths of sutures.

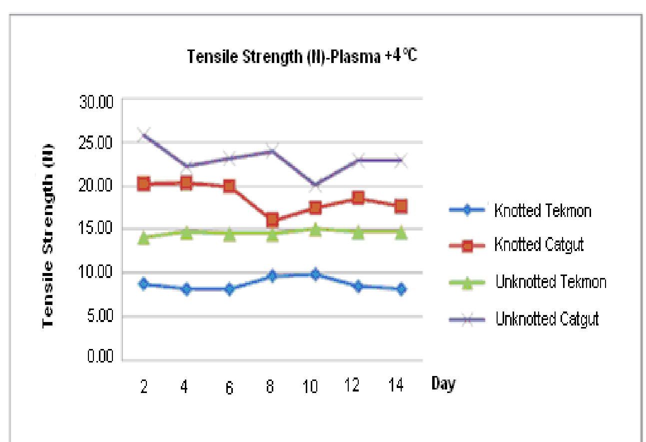

Figure 9. Effects of plasma at +4°C on tensile strengths of sutures.

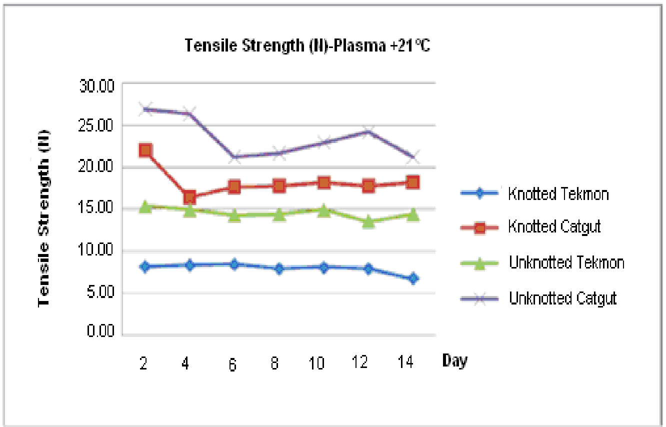

Figure 10. Effects of plasma at +21°C on tensile strengths of sutures.

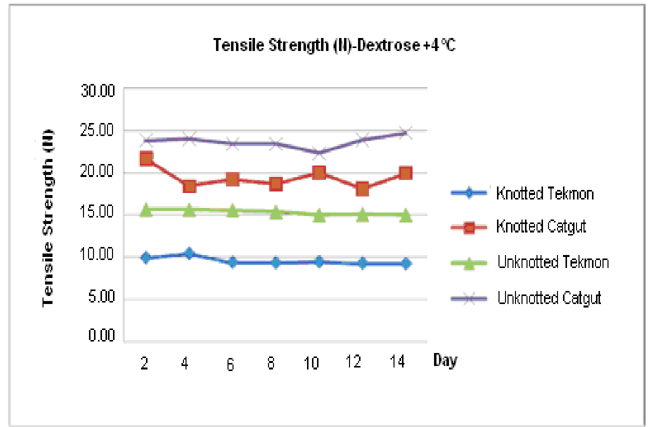

Figure 13. Effects of dextrose at +4°C on tensile strengths of sutures.

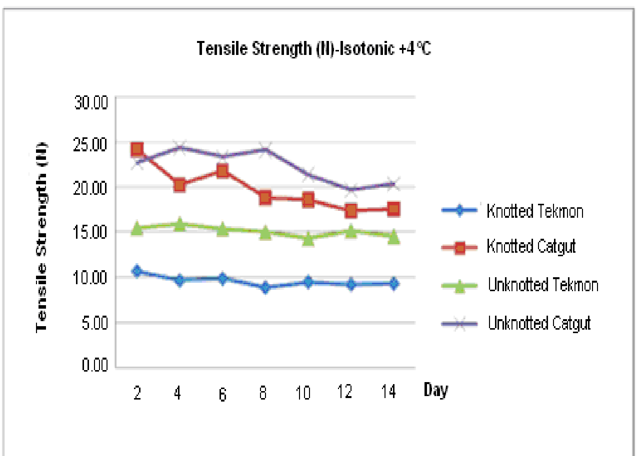

Figure 11. Effects of isotonic at +4°C on tensile strengths of sutures.

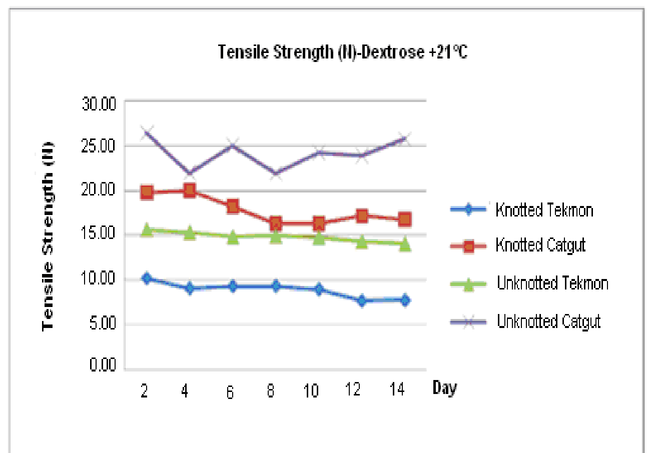

Figure 14. Effects of dextrose at +21°C on tensile strengths of sutures.

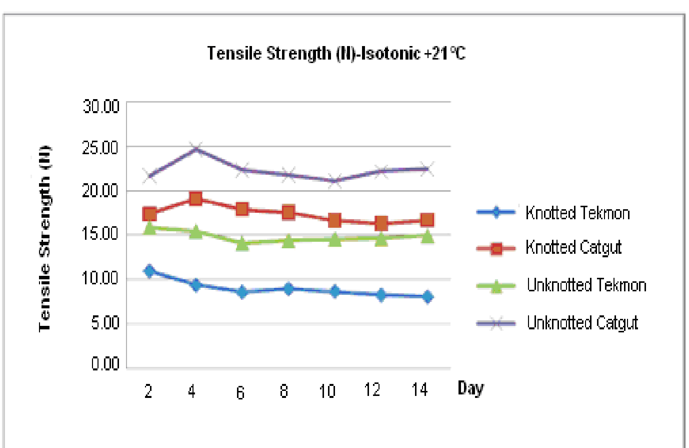

Figure 12. Effects of isotonic at +21°C on tensile strengths of sutures.

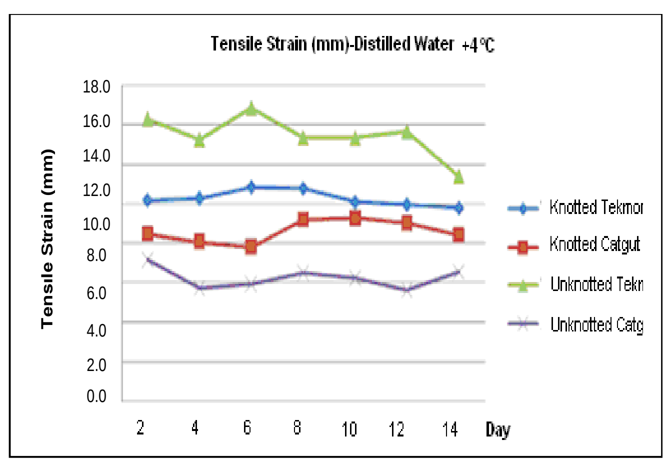

Figure 15. Effect of distilled water at +4°C on tensile strain.

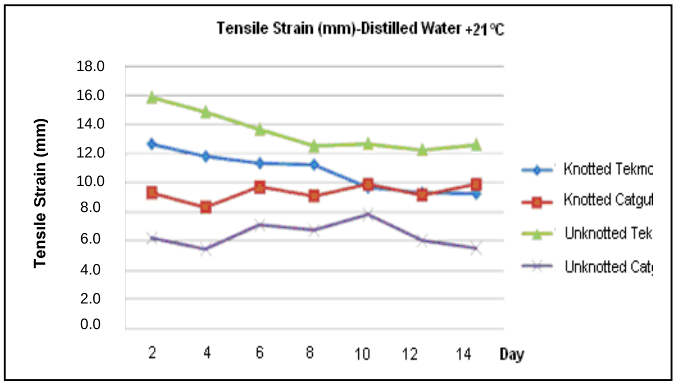

Figure 16. Effect of distilled water at +21°C on tensile strain.

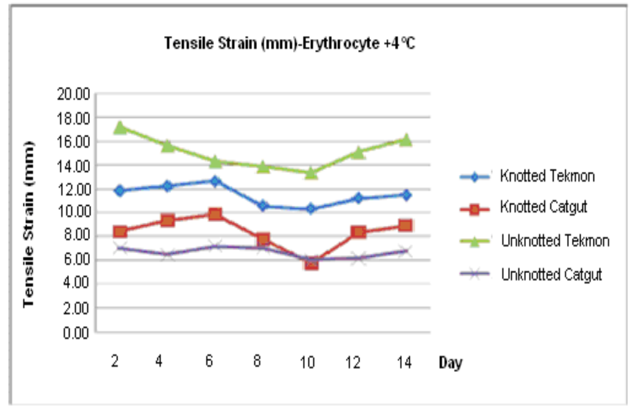

Figure 19. Effect of erythrocyte suspension at +4°C on tensile strain.

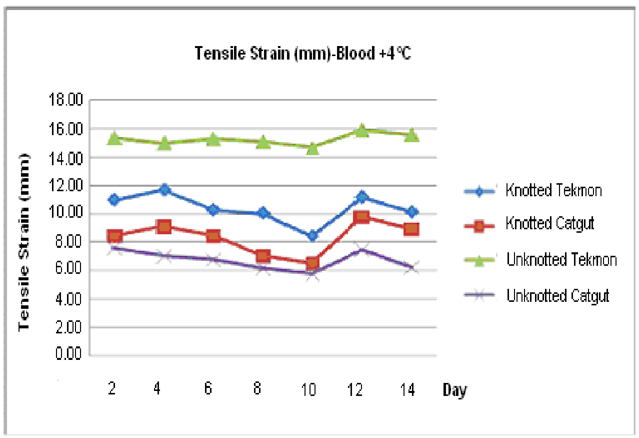

Figure 17. Effect of blood at +4°C on tensile strain.

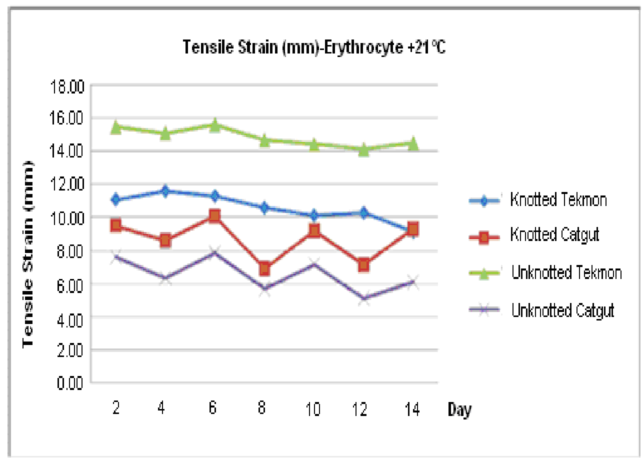

Figure 20. Effect of erythrocyte suspension at +21°C on tensile strain.

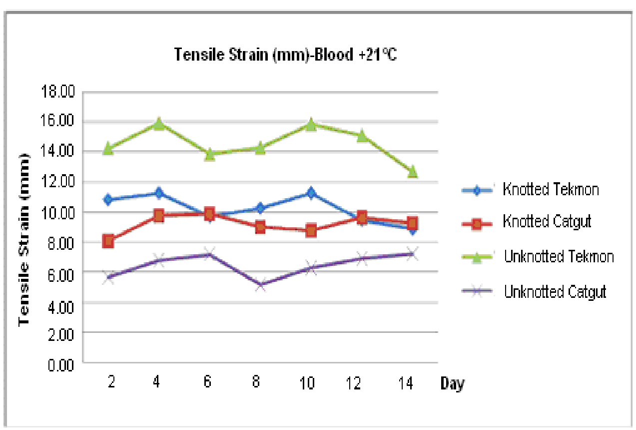

Figure 18. Effect of blood at +21°C on tensile strain.

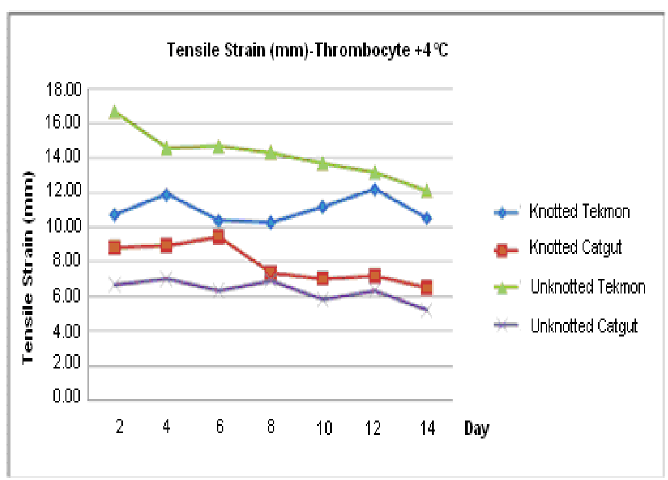

Figure 21. Effect of thrombocyte suspension at +4°C on tensile strain.

catguts had lower tensile strains. Catguts were clearly deformed from erythrocyte solution, especially at higher temperatures (Figures 21 and 22).

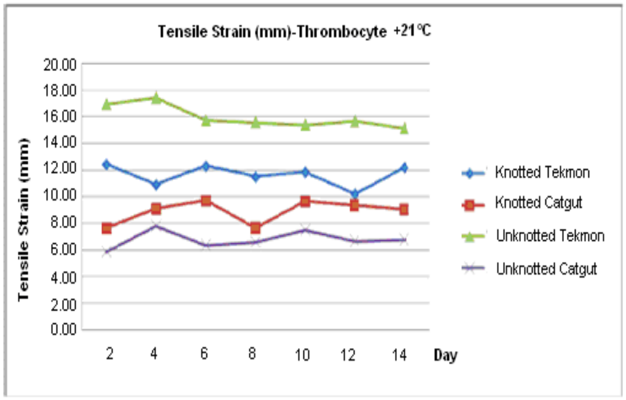

Figure 22. Effect of thrombocyte suspension at +21°C on tensile strain.

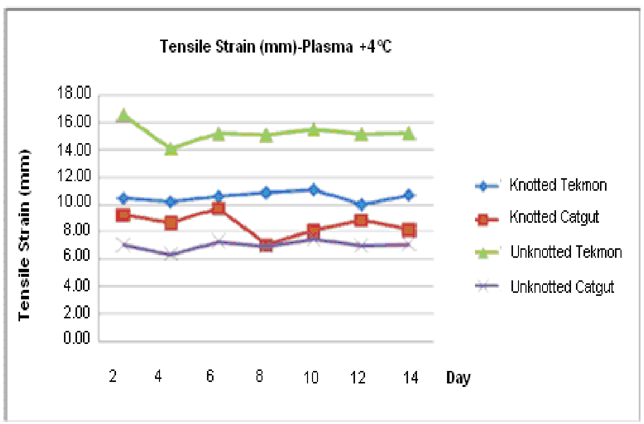

Figure 23. Effect of plasma at +4°C on tensile strain.

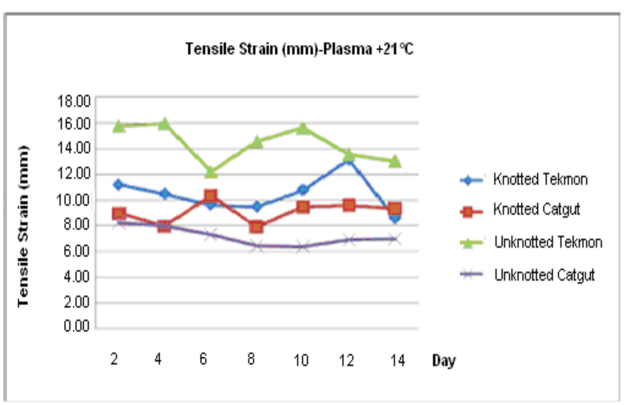

Figure 24. Effect of plasma at +21°C on tensile strain.

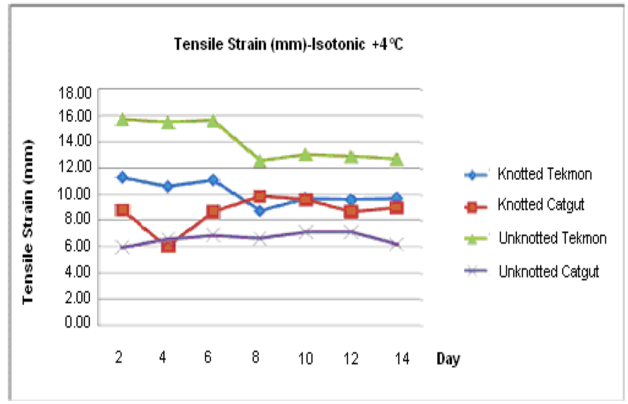

Figure 25. Effect of isotonic at +4°C on tensile strain.

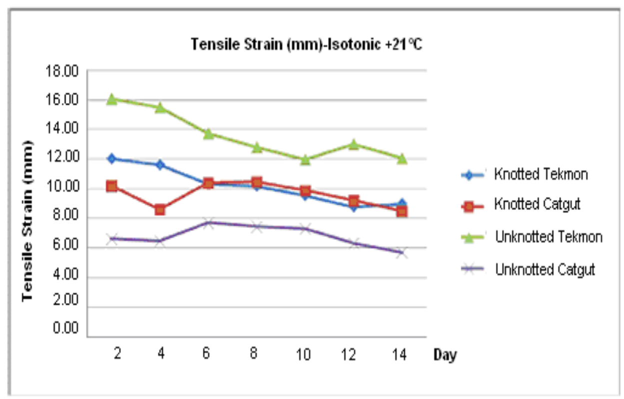

Figure 26. Effect of isotonic at +21°C on tensile strain.

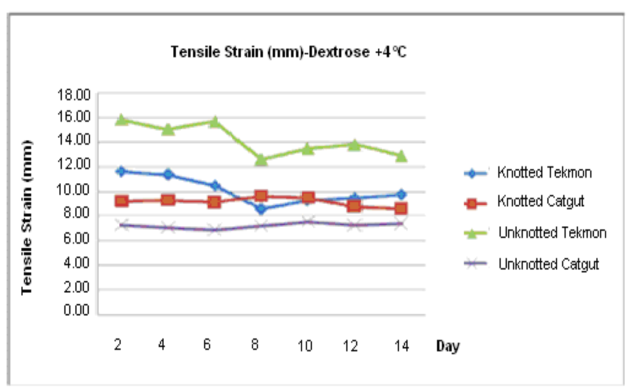

Figure 27. Effect of dextrose at +4°C on tensile strain.

Both unknotted and knotted catguts showed less dimensional stability in thrombocyte, even at 4°C (Figures 23, 24, 25 and 26).

As being different from other suspensions, tensile strains of tekmon sutures were changed in isotonic and plasma. Characteristics of catgut sutures were affected from medical liquid type, not from temperature increase (Figures 27 and 28).

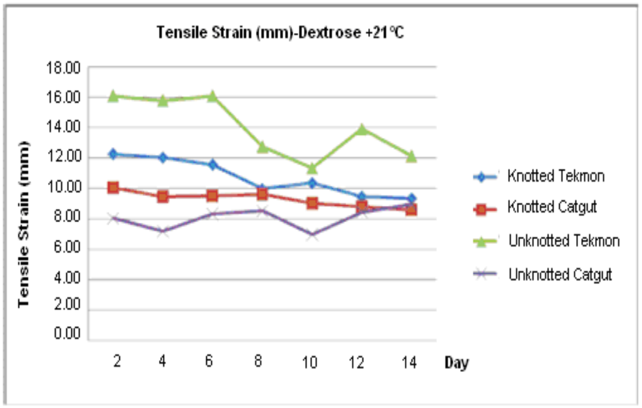

Figure 28. Effect of dextrose at +21°C on tensile strain.

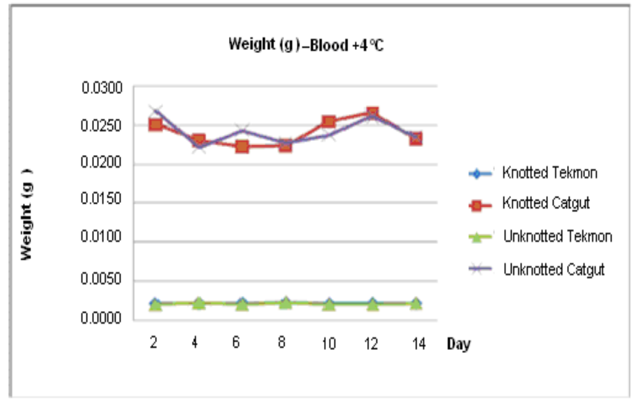

Figure 31. Effects of blood at +4°C on suture weights.

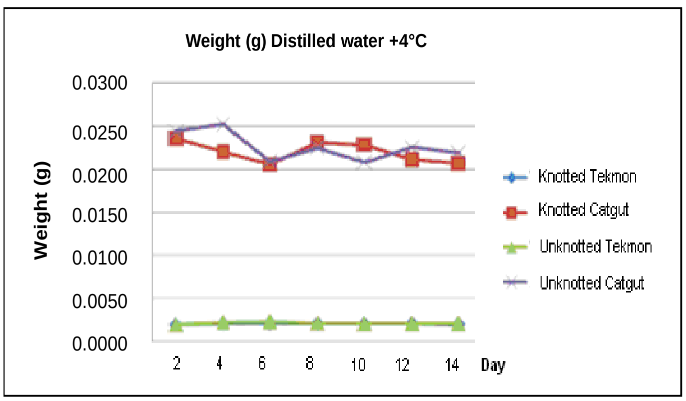

Figure 29. Effects of distilled water at +4°C on suture weights.

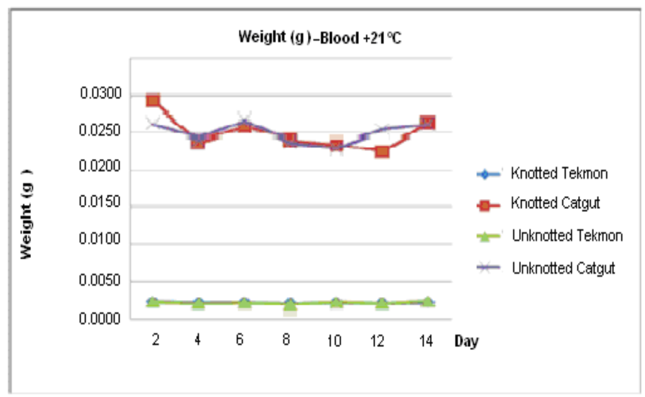

Figure 32. Effects of blood at +21°C on suture weights.

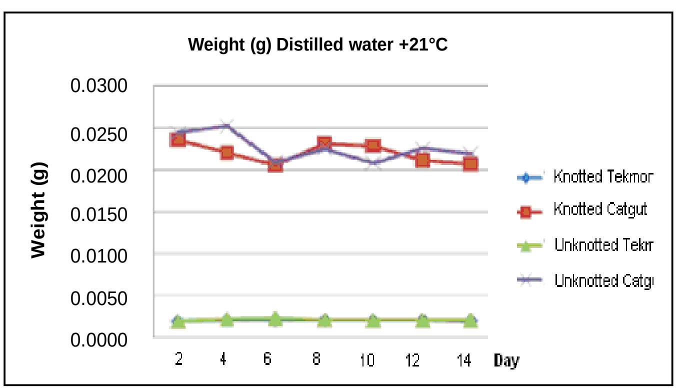

Figure 30. Effects of distilled water at +21°C on suture weights.

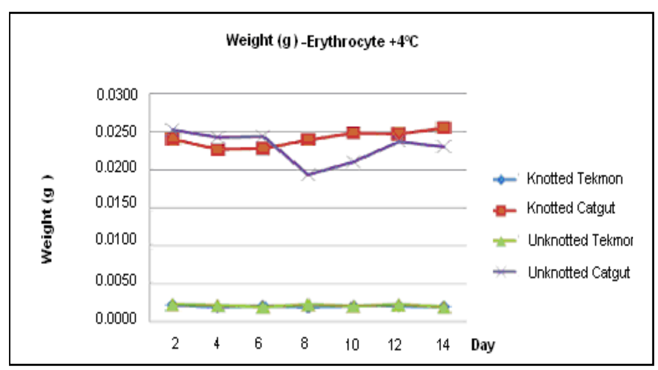

Figure 33. Effects of erythrocyte suspension at +4°C on suture weights.

Same amount of dextrose caused more deformation on tekmon sutures. A sharp decrease was seen in unknotted tekmon sutures at 21°C. Changes on tensile strengths of catgut sutures were negligible both at lower and higher temperatures (Figures 29, 30, 31 and 32).

Weights of tekmon samples were the same at +21 and +4°C in both distilled water and blood. Weight differences of knotted and unknotted catguts were negligible and nearly the same with each other (Figures 33 and 34).

Erythrocyte suspension did not cause any change in

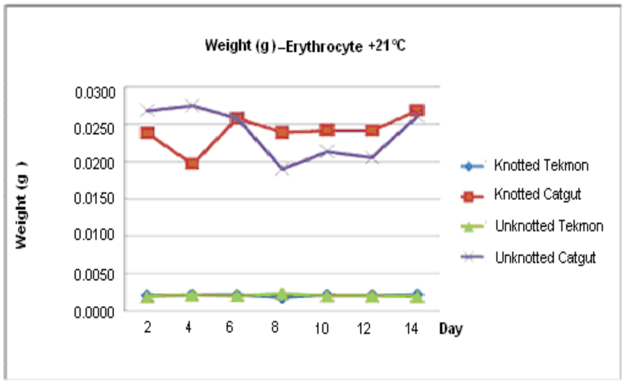

Figure 34. Effects of erythrocyte suspension at +21 °C on suture weights.

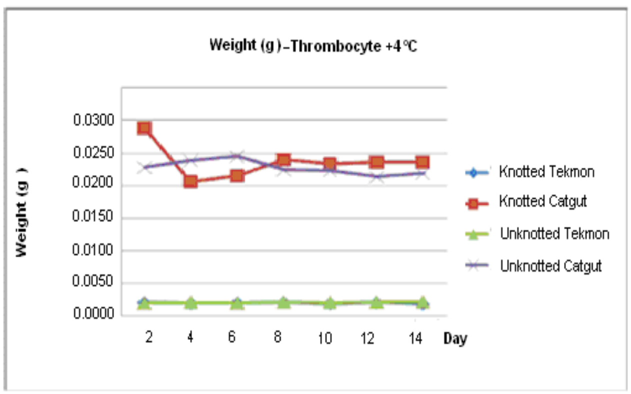

Figure 35. Effects of thrombocyte suspension at +4°C on suture weights.

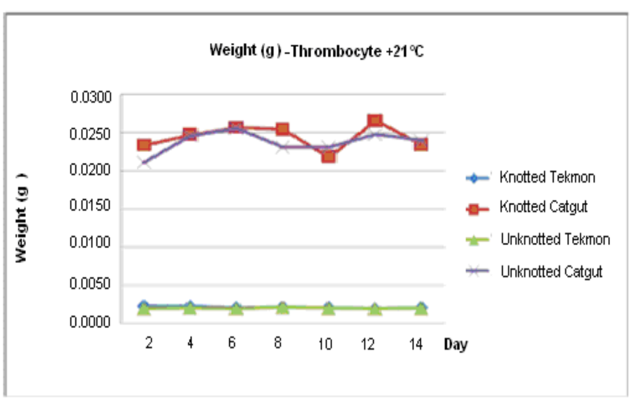

Figure 36. Effects of thrombocyte suspension at +21°C on suture weights.

tekmon sutures' weights. However catguts were affected from erythrocyte solution at 4 and 21°C (Figures 35 and 36).

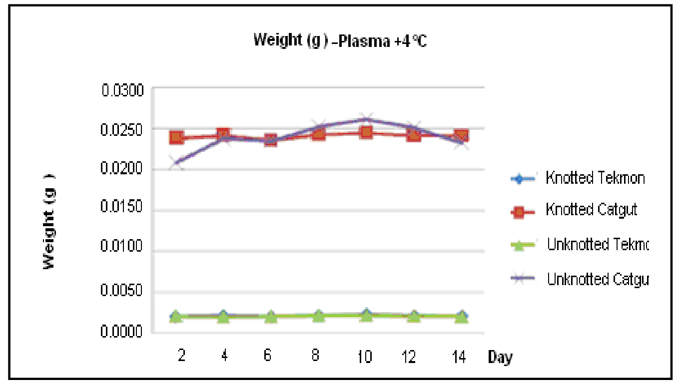

Figure 37. Effects of plasma at +4°C on suture weights.

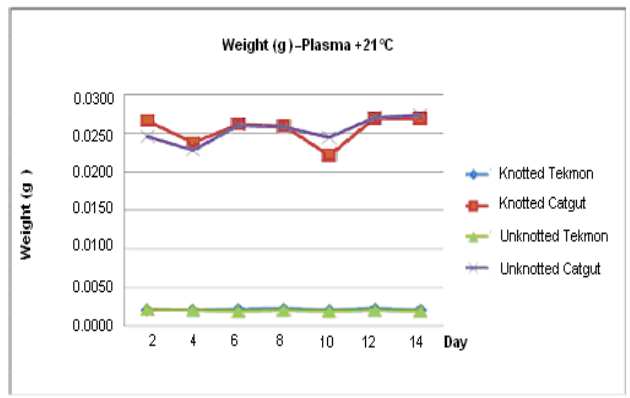

Figure 38. Effects of plasma at +21°C on suture weights.

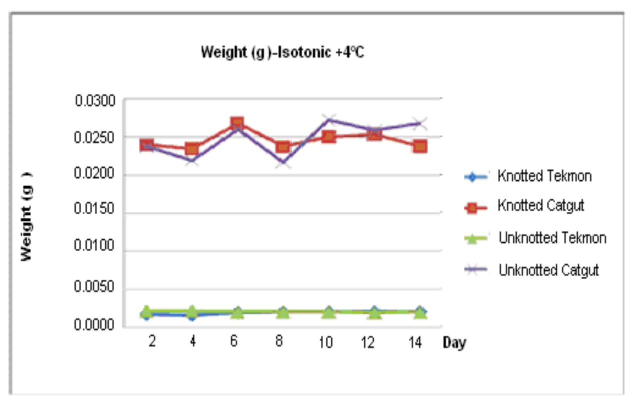

Figure 39. Effects of isotonic at +4°C on suture weights.

For both tekmon and catgut sutures, there was not considerable change resulted from thrombocyte and temperature increase (Figures 37 and 38).

Keeping sutures in plasma did not cause weight difference (Figures 39 and 40).

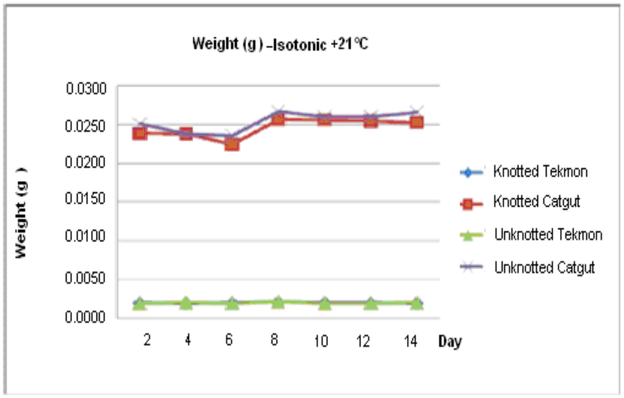

Figure 40. Effects of isotonic at +21°C on suture weights.

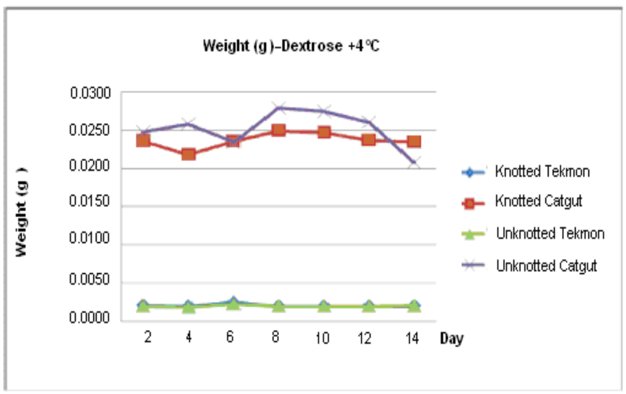

Figure 41. Effects of dextrose at +4°C on suture weights.

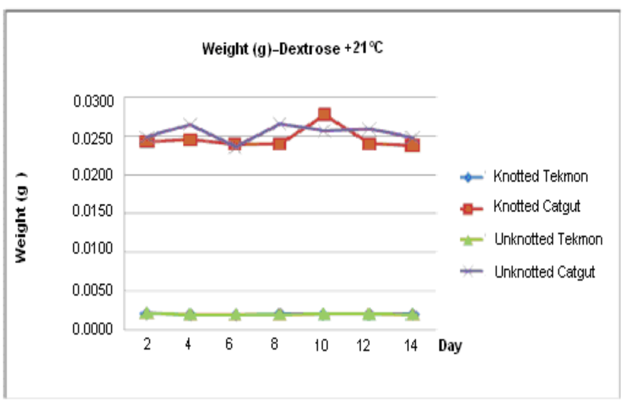

Figure 42. Effects of dextrose at +21°C on suture weights.

Although isotonic solution had an important effect on tensile strains of sutures, it did not decrease or increase weights of sutures significantly. There was no considerable effect of keeping sutures in different temperatures, too (Figures 41 and 42). Sutures, which were exposed to dextrose solution, kept their weights at 4 and 21°C.

DISCUSSION

A material, which will be implanted into human body, is mostly exposed to blood. During implantation, it can be also subjected to medical liquids such as: isotonic and dextrose. Therefore, it is very important that how an implanted material will behave with or without knotting.

Tensile strengths of both synthetic and natural sutures decreased in different solutions at different time intervals. But tensile strength of catgut is generally lower. Tensile strengths of samples at +21°C were lower than that of at +4°C. It is shown that temperature has a significant effect on tensile strength of sutures. Tensile strengths of knotted specimens are lower than knotless specimens for both tekmon and catgut sutures.

Tekmon sutures have generally no weight loss but medical liquids cause weight losses on catgut samples. These weight losses can be negligible. Temperature does not cause weight loss.

Tensile strain decreases in different solutions and at different temperatures depending on the time. Tensile strains of tekmon sutures are higher. Knotless tekmon sutures elongate more than knotted tekmon. This is a result of shear force occurred in the knot.

On the other hand, tensile strains of knotted catgut are higher than knotless tekmon. This phenomenon can be explained by insufficient knot tightness. The reason of not having same knot strength is due to more rigid and thicker structure of catgut. Tensile strains of sutures kept at +4°C is higher than sutures kept at +21°C. Increase in temperature causes decrease in tensile strain.

REFERENCES

ASTM D3217–07. Test Methods for Breaking Tenacity of Manufactured Textile Fibers in Loop or Knot Configurations.

Bayraktar Karaca E (1999). Investigating the Effects of Monofilament and Multiple Knitted Structures on Some Mechanical Properties of Silk, Polyamide, Polypropylene Surgical Yarns, PhD Thesis, Uludağ University, Bursa.

Byrne C (2000). 1st Technical Textiles Market-An Overvies in Handbook of Technical Textiles, Woodhead Publishing Limited, Cambridge, England.

Celkan T (2004). Usage of Blood and Blood Products and Their Application Problems, XIII. National Pediatric Cancer Congress, Nursing Program, Nevşehir.

Cireli A, Kılıç B, Sarıışık M, Okur A (2007). Medical Textiles and Their Testing Methods, Turkish Standarts in Packing Materials, 5th National Sterilization&Disinfection Congress, Antalya.

Gemci R, Ulcay Y (2004). Types and Properties of Surgical Threads and Strength Differences between Chrome and Normal Catgut, Journal of Faculty of Engineering and Architecture, Uludag University, 9(2): 95–105.

Gülgönül L (1991). A study on Properties, Productions and Problems of Surgical Sutures Used in Turkey, MSc Thesis, Institute of Science, Ege University, İzmir.

Gürdal BE (1997). Production and Characterization of Polypropylene Surgical Threads, MSc Thesis, Institute of Science, Hacettepe University, Ankara.

Köktürk G (1996). Production and Characterization of Biodegradable Co-polymers and Fibers for Using as Surgical Sutures, MSc Thesis, Institute of Science, Hacettepe University, Ankara.

Shamash K (1989). Textile Month, December 15–16.

Oran E (1999). Collagen-based Biomaterials, MSc Thesis, Institute of Science, Hacettepe University, Ankara.

Rigby AJ, Anand SC (2000). 15th Medical Textiles in Handbook of Technical Textiles, Woodhead Publishing Limited, Cambridge, England.

Uçar S (2006). Technical/Smart Textiles and Their Usages in Design, MSc Thesis, Institute of Social Science, Mimar Sinan Fine Arts University, İstanbul.

Ulcay Y, Karaca E (1993). Materials and Developments of Surgical Sutures and Their Properties, J. Textile-Technic, 9(107): 104–107.

Yükseloğlu SM, Canoğlu S (2003). Nonwoven Fabrics Used in Health and Hygiene, J. Chem. Technol., 29: 64–71.