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Craniosynostosis Surgery and Three-Dimensional Printing Technology

Kraniosinostoz Cerrahisi ve Üç Boyutlu Baskı Teknolojisi Kullanımı

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Abstract: Craniosynostosis is the closure of one or more of the skull sutures before the normal process. The main complications of craniosynostosis surgery reported throughout history; excessive blood loss and transfusion-related reactions, long hospital stay times, length of surgery and perioperative causes of infections, cerebrospinal fluid leaks, dural sinus injuries and calvarial bone deformities as a result of clinical findings since ancient times, although modern surgical treatment methods was carried out in the last century. The aim of surgery for single suture craniocinostosis is to prevent intracranial pressure increase, hydrocephalus, visual disturbances, cognitive retardation and poor aesthetic appearance by eliminating the shape adjustment disorder of the cranium and brain. One of the popular innovations of our day, 3D printers are used more and more in medicine as in every field of life. Thanks to these printers, the symmetrical structure is preserved and a better appearance is obtained from the cosmetic perspective. In terms of usage, there are no significant differences between them. The surgeon's decision on the type of material to be used during surgery and which one is appropriate is important. Using these new generation printers with complex computer programs and production techniques and production techniques, it is possible to reproduce various types of tissue with different texture processing properties.
Keywords: Craniosynostosis, 3D printing, Surgery.

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Özet: Kraniyosinostoz normal işlemden önce bir veya daha fazla kafatasındaki sütürün kapanmasıdır. Kraniosinostoz cerrahisinin ana komplikasyonları tarih boyunca bildirilmiştir; Modern cerrahi tedavi yöntemleri eski olmasına rağmen aşırı kan kaybı ve transfüzyona bağlı reaksiyonlar, uzun hastanede yatış süreleri, ameliyat süreleri ve perioperatif enfeksiyon nedenleri, beyin omurilik sıvısı sızıntıları, dural sinüs yaralanmaları ve klinik bulguların sonucu olarak görülen kalvariyal kemik deformiteleri geçen yüzyılda gerçekleştirildi. Tek sütürlü kraniyositozis ameliyatının amacı kafa içi basınç artışını, hidrosefali, görme bozukluklarını, bilişsel geriliği ve kötü estetik görünümü engellemek ve kafatasının ve beynin şekil ayarlama bozukluğunu ortadan kaldırmaktır. Günümüzün popüler yeniliklerinden biri olan 3D yazıcılar tıpta yaşamın her alanında olduğu gibi giderek daha fazla kullanılıyor. Bu yazıcılar sayesinde simetrik yapı korunmuş ve kozmetik açıdan daha iyi bir görünüm elde edilmiştir. Kullanım açısından aralarında önemli bir fark yoktur. Cerrahın ameliyat sırasında kullanılacak malzeme türüne ve hangisinin uygun olduğuna karar vermesi önemlidir. Bu yeni nesil yazıcıları karmaşık bilgisayar programları ve üretim teknikleri ve üretim teknikleriyle kullanarak, farklı doku işleme özelliklerine sahip çeşitli doku türlerini çoğaltmak mümkündür.
Anahtar Kelimeler: Kraniosinostoz, 3B Yazdırma, Cerrahi.

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1. Introduction

Craniosynostosis is the closure of one or more of the skull sutures before the normal process. The main complications of craniosynostosis surgery reported throughout history; excessive blood loss and transfusion-related reactions, long hospital stay times, length of surgery and perioperative causes of infections, cerebrospinal fluid leaks, dural sinus injuries and calvarial bone deformities as a result of clinical findings since ancient times, although modern surgical treatment methods was carried out in the last century. In the historical development, the pathophysiology of the disease and the time of surgical treatment were learned, and these complications were significantly decreased with the advances in surgical treatment methods, and cosmetic and functional results were achieved (1,2).

Overall prevalence is around 1/2500. It is divided into two main groups as syndromic and nonsendromic. Syndromic craniosynostoses constitute about 15-20% of all craniosynostoses. Apert and Crouzon Syndromes are the most common. Nonsendromic craniosynostoses constitute a large group of 80-85%. Sagittal synostosis is most common. Corneal synostosis group consists of 20-30% of all surgical cases (3,4).

Skull Disorder

In cases where a single suture is affected, there is an overgrowth of other sutures in order to tolerate this because there is no growth in the affected suture. Accordingly, different shape disorders occur in the head according to the closed suture line. Metopathic suture synostosis should be considered if bilateral hypoplasic frontal bone and a sharp protruding forehead (triangular head-trigonosephaly) occur. The anteroposterior diameter of the head is shorter than normal; anterior plagiocephaly (unilateral coronal synostosis) should be considered if the orbital is asymmetrical, that side is small, and the flattened clown's eye (the cranium is an elliptical ellipse). If the head expands upwards and to the sides, the orbits cannot develop well, and there is a tower head view bracephaly, bilateral coronal synostosis should be considered. Sagittal suture synostosis (skaphosephaly) should be considered when there are balloons at both ends, a long and flat head (dolicosephaly) or parietal bones like cloverleaf on both sides, and hardened and tapered sagittal sutures (Figure 1) (5).

Figure 1.
Graphically, the shape of the head deformity in certain suture synostoses: **A)** Unicoronal suture synostosis (anterior plagiosephaly), **B)** Bilateral coronal synostosis, **C)** Metopathic synostosis (trigonosephaly), **D)** Sagittal synostosis (dolicosephaly).

In the presence of flattening in the occipital area, unilateral lambdoid synostosis (synostotic posterior plagiocephaly) or deformational lambdoid synostosis (positional posterior plagiocephaly) should be considered. Synostotic plagiocephaly is the deformity of the head which develops due to premature closure of unilateral frontal or occipital sutures. It accounts for 0.8-1.3% of all cases of craniosynostosis. Deformal lambdoid synostosis is a developmental abnormality and the deformities that occur because of the shape of the skull with the effect of external forces. The incidence in the general population is one in 300 live births. The most common reason is that babies are always in the same way (usually on their back).

Principles of Treatment

The aim of surgery for single suture craniocinostosis is to prevent intracranial pressure increase, hydrocephalus, visual disturbances, cognitive retardation and poor aesthetic appearance by eliminating the shape adjustment disorder of the cranium and brain. Surgery is usually done one year before. Bones are more suitable for remodeling in the early period. In the late period, the bones become more fragile, so open-crater forming is the more preferred method. Endoscopic sutures, spring-assisted distraction, pi procedure, fronto-orbital advancement, open cranial dome forming are among the surgical methods used.

Three-Dimensional Printing Technology and Craniosynostosis Surgery

One of the popular innovations of our day, 3D printers are used more and more in medicine as in every field of life. Thanks to these printers, the symmetrical structure is preserved and a better appearance is obtained from the cosmetic perspective (6). In terms of usage, there are no significant differences between them. The surgeon's decision on the type of material to be used during surgery and which one is appropriate is important. Using these new generation printers with complex computer programs and production techniques and production techniques, it is possible to reproduce various types of tissue with different texture processing properties (7). The fields of neurosurgery and plastic surgery have shown significant improvements especially as a result of the use of 3D printing. This technology has enabled noninvasive visualization of structures for both diagnosis and surgical treatment; however, most imaging methods, including X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), are rendered in 2D (2D) or 2D slices in 3D (3D) units; structures can be reconstructed from 3D volumes and then produced as physical models, which can then be used for surgical planning and training for both patients and those who receive training. Similarly, 3D printing capabilities can be applied to the design of surgical simulations. Simulations provide a realistic representation of the surgical procedure without the risk of injury to a patient (8).

Craniosynostosis surgery is a reconstruction surgery to protect the intracranial structures of the calvarial formation and is a serious challenge for the surgeon. In patients planned to undergo craniocinostosis surgery, computerized modeling was performed on preoperative axial 1-mm spiral computed tomography. The duration of surgery was shortened with the possibility of preoperative simulation, thus, the effect of patient satisfaction on the surgical plan was provided (Figure 2) (9).

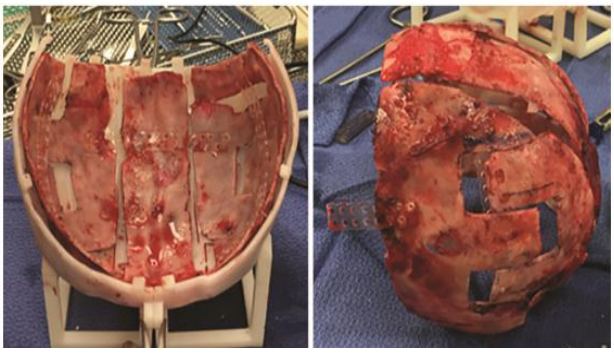

Figure 2.
Left: Fixation of the cut bone parts with absorbable plates and screws in the expansion guides of the cranial mold. **Right:** Extended kalvarial structure.

Depending on the type of material used during craniocinostosis surgery, there is a possibility of developing infection up to 30%. Reconstruction with titanium mesh is a cosmetic method used today and has successful results in terms of reducing infection development. The most important disadvantage is that the cost is high. Combining the use of methyl methacrylate, which is less costly as a material, with 3D

technology has shortened the duration of surgery and caused less complications at low cost, resulting in successful results (10). The advantages of three-dimensional surgical planning are to see the results of different surgical approaches, shorter operative times and successful operations, personalized implant verification. In addition, with the developments in 3D printing technology, the increase in the model production speed and the decrease in the costs of 3-dimensional printed models with pre-surgery planning, surgical simulations and surgery as a guide to use as a guide may be considered as routine practice.

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