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CAD - CAM IN CLEFT LIP AND PALATE PATIENTS: A REVIEW

Dentistry

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ABSTRACT

Cleft lip - palate (CLP) pose a complex challenge in pediatric surgery, requiring precise and customized interventions for optimal outcomes. Over the past 25 years, CAD-CAM (computer-aided design and computer-aided manufacturing) technology has gained recognition in dentistry, proving to be valuable in prosthesis fabrication. Its integration into the treatment of cleft lip and cleft palate highlights its potential to transform pediatric craniofacial care, offering the prospect of enhanced patient outcomes and improved quality of life. In pediatric dentistry, CAD-CAM and 3D printing technologies are increasingly utilized for creating various prostheses, appliances, and dental treatments.

KEYWORDS

CAD-CAM, craniofacial care, 3 D printing, cleft lip, cleft palate.

INTRODUCTION

CLP occur in approximately 1.5 per 1000 live births, translating to around 250,000 new cases annually worldwide. CLP can present as unilateral or bilateral, and may be complete or incomplete. This condition poses a significant public health challenge due to the associated morbidity, its multifactorial origins, and the extensive, multidisciplinary approach required for effective intervention and management.[1] CAD//CAM, which stands for "Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM)", was introduced to the field of dentistry in the mid-1980s.[2] Over more than two decades, CAD/CAM technology has increasingly become an integral component of dental practice. Management of CLP is a protracted process that starts in infancy and extends into adulthood.[3]

With the popularization of such a technology, tremendous growth in several areas of dentistry has potentially benefited from digital impression taking and digital models in maxillofacial prosthetics, restorative dentistry, prosthodontics, orthodontics, dental implantology and even full mouth rehabilitation[(4)]. Prosthesis manufacturing for a non-surgical intervention like Naso-Alveolar Molding (NAM) in CLP also utilizes CAD & CAM. The fore mentioned technology is also utilized to provide younger patients with low-cost pre-surgical plates in cleft palate. Prior to cleft lip surgery, maxillary arch contouring, nasal cartilage reshaping and primary rhinoplasty are accomplished with the use of Naso-Alveolar Molding (NAM).[5] NAM facilitates the positioning and approximation of alveolar cleft segments while simultaneously addressing nasal cartilage and soft tissue abnormalities.[6] The primary goal of presurgical NAM is to reduce the severity of the cleft deformity prior to surgery. This technique offers several advantages in the treatment of cleft lip and palate deformities.[5] Cleft lip and palate can lead to difficulties in feeding, impacting the patient's health and serving as a psychological barrier to normal developmental milestones.[7] Infants with clefts often struggle to generate sufficient suction for feeding from a nipple or breast.[8]

One of the initial treatment options for patients awaiting surgery is the use of a feeding appliance. This appliance covers the defect and helps bridge the gap between the nutritional challenges faced by a malnourished cleft palate patient and the nourishment required for proper growth and development.[7] Integrating CAD//CAM technology into the planning and execution of Le Fort I surgery in pediatric cleft palate patients can enhance surgical precision, optimize outcomes, and improve the overall patient experience and enables the surgeons to accurately determine the extent of bone cuts and movements required to achieve the desired outcome. Preoperative visualization of the procedure is made possible by virtual surgical planning and model design, which also facilitate the design of the intended outcome, the production of surgical guides, and the provision of instruments to confirm that the intended and actual results lineup.[9]

Cad - Cam Uses In Cleft Palate And Lip Pediatric Patients

Feeding Plate / Obturator

Neonates with a cleft palate experience feeding difficulties due to the Oro-nasal communication that impairs their ability to generate the negative pressure required for effective suckling. In this condition, the baby attempts to press the nipple between the tongue and hard palate to extract milk. However, if the cleft is wide, the nipple may become trapped in the defect, rendering this method ineffective. Additionally, feeding complications include nasal regurgitation of food and excessive air intake, which can lead to frequent choking. Consequently, feeding times are significantly prolonged, causing parental anxiety and fatigue for both the baby and the mother.[10] Increased air intake during feeding leads to longer feeding times and can cause the child to become fatigued before finishing a feed (Chase et al., 1990). These difficulties may result in nutritional issues, as breast milk is the optimal source of nutrition for infants. Additionally, recurrent infections, multiple surgeries, and adverse psychosocial factors exacerbate these problems.[11] The concept of early treatment for cleft palate patients using a feeding obturator was pioneered by McNeil in 1956. The feeding obturator is a prosthetic aid which restores the separation between the oral and nasal cavities. The feeding appliance covers the cleft palate and creates a platform toward which the baby can press the nipple and extract milk[10]. To fabricate these plates, an impression of the maxilla is necessary, and the precise management of a palatal cleft impression typically falls under the prosthodontist's expertise. However, obtaining an impression in children, particularly newborns, can be stressful. The main risks associated with this process include airway obstruction, cyanosis, and the potential for impression material to become trapped in undercuts. The advent of digital technologies presents new opportunities for advancements in the field of prosthetic appliances.[12]

Intraoral scanners provide accurate and more comfortable impressions, while dental software facilitates the computer-aided design (CAD) of plates and splints. Additionally, milling and additive manufacturing technologies enable the rapid and cost-effective computer-aided manufacturing (CAM) of prostheses. The development of a passive palatal plate can greatly benefit from these advancements. Utilizing modern technology for the virtual design and fabrication of NAM plates offers significant promise by eliminating the time-consuming and complex process of cleft impressions and reducing the number of laboratory steps involved.[13]

Nasoalveolar Molding Plate (Nam)

Naso-Alveolar Molding (NAM), as described by Grayson and Court (2001) and Grayson and Maull (2004), is a procedure used in infants with cleft conditions to bring the alveolar processes closer together.[13] NAM offers several benefits, including elongating the columella, expanding the cleft nasal mucosa, and enhancing the symmetry of the nasal tip.[14]

This approach improves the contour of the arches and facilitates more effective lip surgeries with reduced scarring. Additionally, it enables the molding of the collapsed alar rim, resulting in an enhanced nasal shape and elongation of the columella.[13]. The concept of pre-surgical Naso-Alveolar Molding (NAM) is grounded in Matsuo's 1984 theory, which posits that the high plasticity of nasal cartilages within the first six weeks after birth is attributed to elevated maternal estrogen levels.[15] Building on this idea, Grayson (1999) developed the first NAM appliance.[16]

Traditional impression-taking methods can be uncomfortable for infants, leading to distress and potential movement during the procedure. The incorporation of CAD/CAM technology in the manufacturing of NAM appliances has streamlined the design and fabrication process, resulting in time savings and a reduction in human error. This advancement has led to minimal need for chairside adjustments. The appliances are now produced with greater precision and standardized dimensions, a level of accuracy that was not achievable with traditional manual methods.[1]

Other advantages include the potential for lower fabrication costs and time. Computer aided design (CAD) enables highly precise 3D measurements of nasal and alveolar development over the course of NAM treatment[17].

In a 2013, Yu et al. demonstrated that CAD-NAM therapy effectively reduced the alveolar gap and corrected the sagittal length of the maxilla. Their findings showed that CAD-NAM successfully decreased the alveolar gap, shortened arch length, and normalized the contours of the maxillary alveolar region.[18] In a 2015 prospective study, Shen et al. demonstrated the effective use of computer-aided manufacturing (CAM) in creating NAM devices. The study also highlighted that 3D technology significantly decreases the need for follow-up visits and appliance adjustments, thereby easing the burden of care and lowering the costs associated with NAM treatment.[19].

CAD/CAM NAM therapy effectively addresses several key aspects, including reducing premaxillary protrusion, total arch length, nasal projection, nasal symmetry, columella length, and nasal width. Additionally, this approach offers the advantages of minimizing chairside adjustment time and providing clinicians with detailed quantitative visual feedback on treatment progress.[20].

Virtual planning (VP) and CAD/CAM-assisted distraction for maxillary hypoplasia in cleft lip and palate patients

In 25-40% of CLP cases, patients exhibit maxillary hypoplasia, which necessitates surgical intervention to correct the resulting dentofacial deformity.[21] Distraction osteogenesis, initially described for orthopedic surgery, has proven to be an effective method for managing various craniofacial deformities. In patients with CLP, this technique has significantly transformed the approach to addressing severe anteroposterior maxillary deficiencies.[22]

In cases of severe midface hypoplasia linked with cleft lip and palate (CLP), distraction osteogenesis (DO) supports gradual bone lengthening and concurrent expansion of the soft tissue envelope. This method helps to counteract the retractive forces of scar tissue, enabling greater movements and minimizing the risk of relapse. Recent advancements in computer-aided design and manufacturing (CAD/CAM) techniques have significantly improved the planning and execution of orthognathic surgery.[21] Virtual surgical planning provides a comprehensive 3D evaluation of the dental arches and surrounding skeletal structures, enabling the simulation of various surgical plans and prediction of their outcomes. Surgeons can generate a detailed virtual model of the dental arch, with treatment plans that can be stored, shared, and easily transferred to the operating room using surgical splints. This approach reduces operation time, patient discomfort, and the overall burden of care, serving as an alternative to traditional model surgery for adult patients with CLP. Virtual surgical planning improves preoperative planning and intraoperative management of midface distraction, offering a cost-effective method that shortens surgical time compared to conventional techniques.[21] CAD/CAM technology further enhances this by allowing precise planning of distraction osteogenesis procedures through virtual surgical planning (VSP), utilizing CT or MRI scans to create three-dimensional models of the patient's anatomy.[22]

The team utilizes CT or MRI scans to create detailed 3D models, allowing for precise visualization of complex anatomical structures and spatial relationships. This capability enhances surgical planning, helps anticipate potential challenges, and enables more effective preparation. Overall, CAD/CAM technology improves the precision, efficiency, and outcomes of distraction osteogenesis procedures in cleft lip and palate cases. By integrating advanced computer-based planning and manufacturing techniques, surgeons can achieve more predictable results, reduce complications, and enhance patient satisfaction.[23]

CONCLUSION

So, CAD/CAM technology represents a transformative approach to the fabrication of feeding plates for cleft palate patients, offering individualized solutions that address their unique anatomical challenges and contribute to better outcomes and quality of life. The ability to design patient-specific NAM devices simplifies the treatment procedure by reducing the time that's needed for device fabrication and adjustment. This not only shortens the time of pre-surgical orthopedic therapy, but also allows for early intervention, which optimize craniofacial growth and development during the vital stages of infancy. The customized fit and adaptability of these devices reduce discomfort and irritation, encouraging better tolerance and acceptance by both patients and caregivers. The integration of CAD/CAM technology into the treatment of CLP in pediatric patients represents a significant advancement in surgical precision, efficiency, and patient outcomes. By leveraging computer-aided design and manufacturing tools, surgeons can meticulously plan procedures, customize surgical interventions, and monitor progress in real-time, leading to improved surgical accuracy and reduced intraoperative complications. CAD/CAM technology enables preoperative planning through virtual surgical simulations, facilitating the precise delineation of osteotomy cuts, distraction vectors, and final segment positioning. Furthermore, real-time monitoring during the distraction phase allows for immediate adjustments based on intraoperative feedback, optimizing the distraction process and improving long-term outcomes. Postoperative assessment comparing actual outcomes to preoperative plans enables surgeons to evaluate efficacy and refine future approaches, contributing to continuous improvement in patient care. All patients, especially those with special needs, can benefit from a partially or completely digital approach to both diagnostic and treatment processes. As this technology continues to advance, it holds great promise for further improving the standard of care in CLP management and enhancing the well-being of affected individuals[25]

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