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The Impact of CAD/CAM Technology on General Dentistry: A Review of Current Trends and Applications

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Abstract: Computer-aided design and manufacturing (CAD/CAM) technology has completely changed dentistry, especially in general practice. These CAD/CAM systems have made dental treatments much more efficient, precise, and predictable by adding digital processes to the mix. This detailed review examines current trends, uses, benefits, and challenges of CAD/CAM technology in general dentistry. We also discuss what's coming next, including developments in artificial intelligence (AI), materials, and cloud-based systems. Even though there are some downsides like expensive costs and a tough learning process, CAD/CAM technology is going to transform how we provide care, leading to patient-focused and innovative solutions in the constantly changing world of dentistry.

Keywords: *CAD/CAM Technology; Digital Dentistry; Restorative Dentistry; AI in Dentistry; Dental Materials.*

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I. INTRODUCTION

Historically, technological advancements have influenced the progress of dentistry and the computer-aided design and computer-aided manufacturing (CAD/CAM) technology has stood out as one of the most important since the beginning of the 21st century. It was developed in the 1980s for industrial purposes, but it wasn't long before the dental community caught on and began using it in the dental profession. The development of CEREC by Mörmann and Brandestini was the first attempt to bring CAD/CAM in the clinical practice use (Mörmann, 2006). Since then, the technology has developed significantly and has become an integral part in fields such as restorative dentistry, prosthodontics, orthodontics, and implantology over the past thirty years.

This article aims to explore the current applications, advantages, and drawbacks of CAD/CAM systems in general dentistry and to focus on promising developments that are shaping the future. As digital dentistry keeps evolving, dental professionals need to understand how to integrate CAD/CAM technology into their daily practice if they want to stay competitive and give their patients the best possible care (Joda et al., 2019).

II. APPLICATIONS IN GENERAL DENTISTRY

CAD/CAM technology is utilized in many different dental procedures, converting old-fashioned workflows into efficient, accurate digital ones.

- *Restorative Dentistry*

CAD/CAM single-visit restorations (crowns, inlays, onlays, and veneers) can be designed and fabricated which cuts down chair time by a lot. Chairside systems such as CEREC let dentists scan, design, and mill restorations right there in the dental office, so they don't need to use the external laboratories (Fasbinder, 2006). Studies have shown that CAD/CAM restorations work just as well as traditional ones, or even better than the conventional ones. Research shows that restorations made with CAD/CAM have marginal fits, strength, and durability that match or beat traditionally made ones (Pjetursson et al., 2007; Bindl & Mörmann, 2005). On top of that, CAD/CAM-supported indirect restorations show less polymerization shrinkage, which helps them last longer clinically (Otto & Schneider, 2008). Being able to mill materials like lithium disilicate and zirconia gives dentists more restoration options.

- *Prosthodontics*

Prosthodontics has seen major improvements with CAD/CAM systems. These systems allow for precise creation of fixed partial dentures, complete dentures, and

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implant-supported prostheses. Digital workflows make impressions much more accurate, which means better fit and fewer adjustments needed (Miyazaki et al., 2009). Studies show that CAD/CAM-made frameworks for full-arch implant-supported prostheses improve passive fit, which reduces mechanical problems (Goodacre et al., 2018). For removable prosthodontic treatments, digital workflows help create complete dentures that fit better and need fewer chairside adjustments (AlHelal et al., 2017). CAD/CAM helps to design custom implant abutments to support the tissue and maintain biomechanical stability.

- *Orthodontics*

CAD/CAM-based digital workflows are commonly used in orthodontics. Systems like Invisalign rely on CAD/CAM to make custom aligners. Furthermore, digital impressions are more comfortable and accurate for patients compared to traditional methods (van der Meer et al., 2012). Digital models replace the need for physical casts, making storage and access much easier (Kravitz et al., 2017).

- *Implantology*

CAD/CAM technology improves implant planning and placement through surgical guides. These guides, which are based on digital scans, make sure implants are placed precisely, leading to better functional and aesthetic results. The virtual implant placement using the cone-beam computed tomography (CBCT) combined with digital impressions increases the precision, leading to the decrease of the surgical risks (van der Meer et al., 2012). Custom-milled abutments and restorations provide better emergence profiles and aesthetic outcomes. Surgical guides made with CAD/CAM ensure precise implant positioning, which minimizes problems during surgery and helps with osseointegration (Jung et al., 2009). Research shows that CAD/CAM-guided surgeries result in less patient discomfort and better long-term success rates (Tahmaseb et al., 2018).

- *Educational Applications*

Dental schools have started using CAD/CAM technology to teach students digital workflows. Virtual simulation platforms allow students to practice digital impressions, design restorations, and mill prostheses before working on real patients (Zitzmann et al., 2019). This approach helps them better understand restorative and prosthodontic principles.

III. BENEFITS OF CAD/CAM TECHNOLOGY

- *Efficiency*

CAD/CAM systems make dental workflows much simpler, reducing treatment time and the number of patient visits. Single-visit restorations are especially helpful for both dentists and patients, causing less disruption to daily routines (Fasbinder, 2006). The fact that the clinician achieves and produces the restoration in his own practice ensures reduced dependence on outside dental laboratories, which speed up the treatment and saves time.

- *Precision and Accuracy*

Digital workflows provide high levels of accuracy, especially when taking impressions and making restorations by getting rid of distortions that traditional materials can cause. The marginal adaptability of CAD/CAM restorations is better than that of the conventionally made restorations, leading to fewer adjustments (Miyazaki et al., 2009). Also, eliminating manual errors that come with traditional impression materials makes prostheses much more consistent and reproducible.

- *Patient Comfort and Satisfaction*

The use of intraoral scanners prevents the pain caused by traditional impression materials. Plus, same-day restorations make things more convenient for patients and increase satisfaction (van der Meer et al., 2012). The digital process also lets patients see their treatment plan, which increases their involvement and confidence in the procedure.

- *Cost-Effectiveness*

CAD/CAM investments are expensive but offer long-term financial advantages in the reduction of laboratory costs and overall practice profitability (Zaruba & Mehl, 2071). By reducing dependence on external laboratories and increasing clinical efficiency, practices can make much more money and provide better experience to their patients.

- *Enhanced Aesthetic Outcomes*

Modern CAD/CAM systems work with a wide range of aesthetic materials, including zirconia and lithium disilicate ceramics, which offer great strength and lifelike translucency. Furthermore, the possibility to precisely match the shade and contours of restorations with natural teeth ensures optimal aesthetic results (Miyazaki et al., 2009).

IV. CHALLENGES AND LIMITATIONS

- *High Initial Investment*

The cost of buying and maintaining CAD/CAM equipment remains a major barrier, especially for smaller practices (Mörmann, 2006). This cost includes possible upgrades as well as continuing maintenance expenses in addition to the gear and software. While long-term savings may eventually offset initial expenses, the financial burden often makes it difficult for new and small-scale practitioners to get started.

- *Learning Curve*

Using CAD/CAM technology requires extensive training for clinicians and staff. It can take a while to become skilled with the software and equipment, often requiring additional certification courses and hands-on training. Continuous learning is also necessary to stay competent and to fully benefit from digital processes as new materials and software updates come out.

- *Material Limitations*

Although materials compatible with CAD/CAM have improved, some ceramics and metals aren't suitable for chairside milling, which limits treatment options (Miyazaki et al., 2009). While CAD/CAM technologies have improved

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in their ability to mill a number of materials, some restorations require laboratory processing to achieve optimal strength and esthetics. In addition, the precision of milling can sometimes be influenced by the properties of individual materials, and it makes occasional postprocessing adjustments necessary.

- *Technical Dependence*

Being heavily dependent on software and hardware can create risks like software problems, system failures, and scanner calibration issues that can disrupt workflows and delay treatments (Joda et al., 2019). Many CAD/CAM systems are proprietary, meaning software and hardware from different manufacturers may not work together perfectly. This lack of standardization can cause workflow inefficiencies, requiring extra time for file conversions and modifications to get seamless integration.

- *Potential for Errors in Digital Scanning*

Even though digital impressions improve accuracy, errors can still happen because of improper scanning techniques or poor intraoral conditions. Saliva reflection, soft tissue displacement/opening, and patient discomfort are also factors that may impact scan quality resulting in inaccuracies that need to be compensated in the final restoration.

V. FUTURE TRENDS IN CAD/CAM DENTISTRY

- *Integration with Artificial Intelligence (AI)*

AI-powered algorithms are going to enhance CAD/CAM capabilities by automating design processes, finding preparation errors, and optimizing occlusion (Schwendicke et al., 2020). Machine learning algorithms can look at huge datasets to recommend optimal restoration designs and adjust treatment plans dynamically based on real-time data. This is where AI-supported planning will further optimize digital workflows, acting without the need for manual influence.

- *Advances in Materials*

The introduction of high-performance hybrid ceramics and bioactive materials will expand CAD/CAM uses, improving strength, aesthetics, and biocompatibility (Denry & Kelly, 2014). Additionally, advances in 3D printing and multi-layered ceramic blocks offer more customization options for dental restorations.

- *Cloud-Based Workflows*

With the cloud integration, dental offices and labs are able to communicate seamlessly, allowing for virtual collaboration and designing. This increases efficiency and reduces turnaround times. Dental professionals can collaborate in real time using digital case-sharing platforms, which improves treatment coordination and speeds up prosthesis fabrication turnaround times. Cloud storage enables remote treatment planning, making CAD/CAM technology accessible to a wider range of practitioners.

- *Patient-Centered Innovations*

Future developments in CAD/CAM technology will focus on personalized treatment options, including customized prostheses and aesthetic restorations tailored to individual needs. As digital scanning and AI-based data analysis continues to grow and improve, CAD/CAM technology is heading towards personalized tailored treatments. Patient-specific occlusal analysis and bite simulations ensure that restorations fit not only functionally but also ergonomically, leading to better long-term success rates.

VI. CONCLUSION

CAD/CAM technology has significantly transformed modern dentistry by improving accuracy, productivity, and patient satisfaction. Integrating digital workflows has changed prosthetic and restorative procedures, improving patient experiences and clinical results. Ongoing advances in AI, materials, and cloud-based systems will further enhance its capabilities, despite challenges like high costs and training requirements. By incorporating CAD/CAM technology, general practitioners can improve clinical treatment and set new standards for dental excellence.

The future of CAD/CAM dentistry looks bright with the combination of chairside 3D printing, cloud-based workflows, improved biomaterials, and artificial intelligence. These developments will not only improve existing procedures but will make digital solutions more widely available to a broader range of dental professionals. As research and development continue to push the boundaries of what's possible, CAD/CAM technology will definitely shape the next generation of dental treatment, making high-quality, same-day restorations more effective and affordable than ever before.

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