Review Article

Classifications and Properties of Materials for Chairside Computer-Aided Design/Computer-Aided Manufacturing Dentistry: A Review

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ARTICLE INFO

Article History

Received:Nov 2020

Accepted: Dec 2020

ePublished:Feb 2021

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ABSTRACT

Background and Aim: Chairside computer-aided design/computer-aided manufacturing (CAD/CAM) systems have become considerably more accurate, reliable, efficient, fast, and prevalent since 1985 when CEREC was introduced. The inceptive restorative material option for chairside CAD/CAM restorations was limited to ceramic blocks. Today, restorative material options have been multiplied and include metal alloys, ceramics, oxide ceramics, resins, and resin-matrix ceramics (RMC). This study aimed at making an overview of chairside CAD/CAM system materials and classifications.

Materials and Methods: An electronic search of the literature was carried out mainly through PubMed, ScienceDirect, Cochrane Library, and Google Scholar. The search aimed at collecting all the relevant English articles from 1965 to 2020.

Result: The analysis of the bond strength, fatigue resistance, flexural strength, elastic constants, microstructural characterization, accuracy, and clinical success of the materials showed variable outcomes. The marginal adaptation of resin ceramics has been reported to be comparable to that of lithium disilicate. It has been reported that the chairside CAD/CAM system using intraoral scanning is at least as accurate as the conventional method.

Conclusion: Chairside CAD/CAM restorations are fast, reliable, predictable, effective, patient-friendly, and cost-effective treatment options. Design software and intraoral scanners have made the treatment procedure simple. Chairside individualization of dental restorations could help improve patient satisfaction. However, considering the limited long-term clinical data, future studies need to address the long-term clinical performance of chairside CAD/CAM materials.

Keywords: Ceramics, Computer-Aided Design, Surface Properties, Treatment Outcome

J Res Dent Maxillofac Sci 2021;6(2):36-50.

Introduction:

The computer-aided design (CAD)/computer-aided manufacturing (CAM) technology has been improving since 1985 when the CEREC system introduced the first chairside CAD/CAM. [1,2]

Numerous chairside CAD/CAM systems are available in the market, including Planmeca (Planscan/Planmill-D4D Technologies, Richardson, TX, USA), Carestream CS solutions (Carestream Dental, Atlanta, GA, USA), and Fast scan (Glidewell, Newport Beach, CA, USA).[3]

A large number of new CAD/CAM materials are available in the market, including Dentsply, Ivoclar-Vivadent, VITA Zahnfabrik, and Lava Ultimate (3M) products.(2,4,5) The conventional methods have been error-prone, complex, technique sensitive, time-consuming, and unpredictable.(6,7) On the other hand, CAD/CAM systems have become considerably more accurate, efficient, and less expensive and allow the restoration to be manufactured in a single appointment. (6-9) CAD/CAM systems are divided into labside CAD/CAM system and chairside CAD/CAM system. In the labside CAD/CAM system, conventional impressions are taken, and then, the stone cast is scanned by an extraoral laboratory scanner, and the prosthesis is designed by the CAD software and then manufactured. With the chairside CAD/CAM system, all the manufacturing steps are done in the dental office, and all the components are in the dental office.(10)

CAD/CAM restorations are commonly fabricated in dental laboratories. There are different software programs for clinical and laboratory CAD/CAM.(11) Chairside CAD/CAM technology has some advantages such as easy and selective repeatability, speed, elimination of transport and delivery fees, easy archivability, material saving, patient satisfaction, true color display for dental and gingival visualization. However, it has some disadvantages such as learning curve, cost, sensitive scanning strategy, software error, and dry working field while scanning. (3)

Chairside CAD/CAM restorative materials have been studied for over 30 years. Dental restorative materials are now produced as blocks (cuboid) or blank (disc) and can be cut to a customized shape and size using wet grinding.(4,7,12) Dental ceramics were the first restorative materials for chairside CAD/CAM. Resin composites are the most commonly used materials in restorative dentistry and prosthodontics.(6,7,9,13)

Restorative chairside options now include polymethyl methacrylate (PMMA)-based materials, composites resins, resin-based ceramics, hybrid ceramics, silicate ceramics, feldspathic ceramics, traditional feldspathic ceramics, leucite-reinforced glass-ceramics, lithium silicate ceramics, lithium disilicate ceramics, zirconia-reinforced lithium silicate ceramics, oxide ceramics, zirconium dioxide ceramics, polycrystalline ceramics, and nanoceramics. (14)
Hybrid ceramics (a mixture of resin and ceramic) are a new category of chairside CAD/CAM materials.
Polymer-containing CAD/CAM materials have shown smoother crowns and less chipping at the margins after milling.(15) It is clear that the material's microstructure and crystalline phase influence the clinical performance, mechanical properties, and aesthetics. (2,9)

The indications for chairside CAD/CAM materials include anterior teeth inlays, onlays, veneers, and posterior crowns. "Polymer-infiltrated ceramic-network (PICN)" and high-performance polymers (HPP) are groups of hybrid materials with 3M and Vita being the first introducers.(6,9,13) The advantages of nanoceramics compared to conventional blocks include superior mechanical properties, better machinability, and smoother milled margins.(16,17) The improvement of intraoral scanners, design software, three-dimensional (3D) printing, and materials' quality and nature has led us to user-friendly multiple options. Chairside CAD/CAM procedure allows doing all treatment steps, from preparation to prosthesis fabrication, in the dental office.(10) This study aimed at making an overview of chairside CAD/CAM materials and classifications to choose the best chairside material in treatment planning. In this review, we evaluate the indications and properties of these materials, including the bond strength, fatigue resistance, flexural strength, elastic constants, microstructural characterization, accuracy, and optical and clinical outcomes.

Materials and Methods:

An electronic search of the literature was done mainly through PubMed, ScienceDirect, Cochrane Library, and Google Scholar databases using the following keywords: "CAD/CAM" and "chairside" and "CAD/CAM" or "nano" or "ceramic" or "dental material" or "digital dentistry" or "resin". The search aimed at collecting all the relevant English articles from 1965 to 2020. Fifty-seven articles were selected. The selection criteria are explained in the algorithm of the selection method in Figure 1. Recent studies on chairside CAD/CAM materials are mentioned in Table 1.

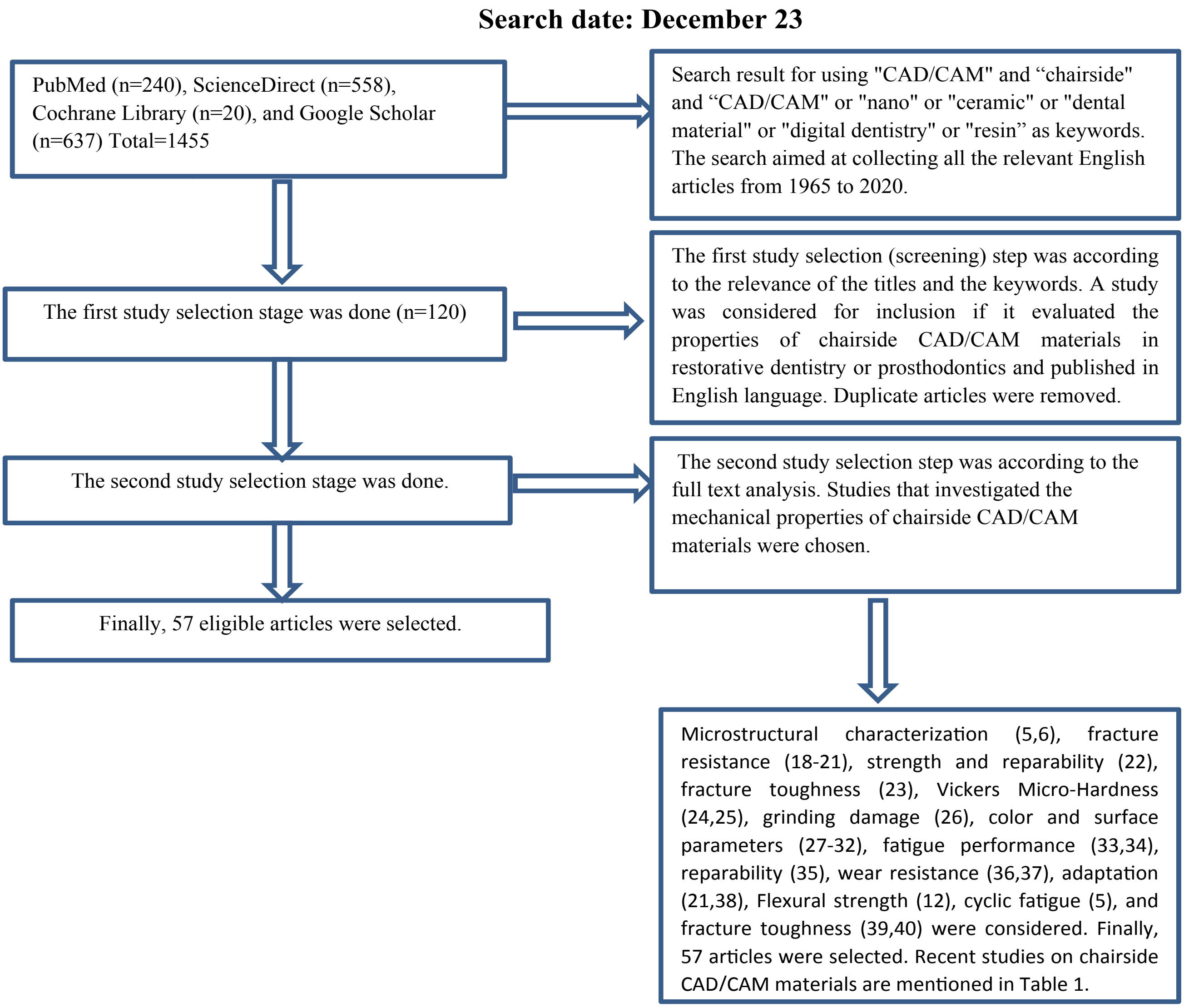

Figure 1: Algorithm of the article selection method

Table 1: Recent studies on chairside CAD/CAM materials

Author/Year	Title/Reference number	Properties	Materials	Results
García-Engra et al 2020	Fracture resistance of new metal-free materials used for CAD-CAM fabrication of partial posterior restorations. (20)	Fracture resistance	Lithium disilicate (LDS) group (control group): IPS e.max CAD®; zirconium-reinforced lithium silicate (ZRLS) group: VITA SUPRINITY®; polymer-infiltrated ceramic networks (PICN) group: VITA ENAMIC®; resin nanoceramics (RNC) group: LAVA™ ULTIMATE	Lithium disilicate had the highest resistance, and resin nanoceramics had the lowest resistance.
Sismanoglu et al 2020	Influence of different surface treatments and universal adhesives on the repair of CAD-CAM composite resins: an in vitro study. (36)	Reparability	Brilliant Crios, Lava Ultimate, Shofu Block HC, and Vita Enamic	Vita Enamic had the highest mean bond strength
Gul and Altınok-Uygun 2020	Repair bond strength of resin composite to three aged CAD/CAM blocks using different repair systems. (22)	Strength and reparability	Lava Ultimate, Cerasmart, and Vitablocs Mark II	The Vitablocs Mark II group showed the lowest strength.
Kanat-Ertürk 2020	Color stability of CAD/CAM ceramics prepared with different surface finishing procedures. (27)	Color stability	Lithium disilicate glass-ceramic (IPS e.max CAD HT) and zirconia-reinforced lithium silicate ceramic (Vita Suprinity HT)	Lithium disilicate showed higher color stability
Lf et al 2020	Fatigue performance of distinct CAD/CAM dental ceramics. (33)	Surface roughness (polished vs. CAD/CAM milling roughness simulation)	FC-feldspathic; PICN-polymer-infiltrated ceramic-network; ZLS- zirconia-reinforced lithium silicate glass-ceramic; LD-lithium disilicate glass-ceramic; YZ-yttria-stabilized tetragonal zirconia polycrystal	CAD/CAM milling had poor fatigue performance
Saglam et al 2020	Marginal adaptation and fracture resistance of feldspathic and polymer-infiltrated ceramic network CAD/CAM endocrowns for maxillary premolars. (38)	Marginal adaptation and fracture resistance of ceramic blocks	Feldspathic and polymer-infiltrated ceramic network (PICN)	No significant differences in marginal adaptation/ Enamic presented significantly higher fracture resistance when compared to Cerec
Fasbinder et al 2019	Clinical evaluation of chairside Computer Assisted Design/Computer Assisted Machining nano-ceramic restorations: Five-year status. (4)	Fracture resistance	Leucite-reinforced ceramic (IPS EmpressCAD/Ivoclar Vivadent AGBendererstrasse 2FL-9494 Schaan, Liechtenstein) nanoceramic (Lava Ultimate/3M)	Nanoceramic onlays performed equally as well as glass-ceramic onlays (after 5 years)
Gwon et al 2019	Wear characteristics of dental ceramic CAD/CAM materials opposing various dental composite resins. (36)	Wear characteristics	MI Gracefil, Gradia Direct P, Estelite Σ Quick, and Filtek Supreme Ultra	Zirconia showed a less volumetric loss
Kurtulmus-Yilmaz et al 2019	The effect of surface treatments on the mechanical and optical behaviors of CAD/CAM restorative materials. (32)	Blocks/ mechanical and optical properties	Lithium disilicate ceramic (IPS e.max CAD), resin nanoceramics (Lava Ultimate, GC Cerasmart), polymer-infiltrated ceramic network material (Vita Enamic)	Lithium disilicate rendered an unpredictable color change
Hampe et al 2019	Fracture toughness analysis of ceramic and resin composite CAD/CAM material. (23)	Fracture toughness of milling blocks	Ambarino High-Class, Brilliant Crios, Cerasmart, exp. CAD/CAM composite, Katana Avencia, Lava Ultimate, VITA Enamic, IPS Empress CAD, and IPS e.max CAD	Lithium disilicate ceramic IPS e.max CAD and leucite-reinforced ceramic IPS Empress CAD showed the highest and lowest K_{Ic} values, respectively ($P<0.001$). VITA Enamic revealed microstructural inhomogeneities and microcracks

Colombo et al 2019	Vickers micro-hardness of new restorative CAD/CAM dental materials: evaluation and comparison after exposure to acidic drink. (24)	Block/change of surface micro-hardness	Hybrid ceramic (CERASMART™, GC Corp., Tokyo, Japan), a resin nanoceramic (Lava™ Ultimate, 3M, Monrovia, CA, USA), a nanohybrid composite (Grandio blocs, VOCO GmbH, Cuxhaven, Germany), and a zirconia-reinforced lithium silicate glass-ceramic (VITA SUPRINITY® PC; VITA Zahnfabrik, Bad Säckingen, Germany)	Zirconia-reinforced lithium silicate glass-ceramic rendered the lowest percentage of micro-hardness loss
Furtado de Mendonca et al 2019	Microstructural and mechanical characterization of CAD/CAM materials for monolithic dental restorations. (6)	Microhardness (Vickers indentation)	Lithium disilicate (LD; IPS e.max CAD)/zirconia-reinforced lithium silicate (ZLS; VITA Suprinity)/hybrid polymer-infiltrated ceramic network (PICN) (VITA Enamic)/hybrid high-performance polymer (HPP) composite resin (GC Cerasmart)	LD: the highest flexural strength (P<0.0001) followed by ZLS, HPP, and PICN HPP: the lowest flexural modulus and hardness ZLS: the highest flexural modulus and hardness. LD: the highest modulus of resilience PICN: the lowest modulus of resilience
Gasparik et al 2019	Effect of accelerated staining and bleaching on chairside CAD/CAM materials with high and low translucency. (28)	Staining and bleaching	Filtek Ultimate (3M) Lava Ultimate (3M) Crios Brilliant (Coltene) Shofu blocks HC Vita Enamic (Vita Zahnfabrik), IPS e.max CAD (Ivoclar Vivadent), Vita Blocs mark II (Vita Zahnfabrik)	The greatest and lowest color changes for staining were reported for Lava Ultimate and e.max CAD, respectively.
Naffah et al 2019	Evaluation of the adaptation and fracture resistance of three CAD-CAM resin ceramics: an in vitro study. (21)	Internal fit and fracture resistance	GC Cerasmart, Vita Enamic, Coltène Brilliant Crios, and e.max CAD	Marginal adaptation of resin ceramics was comparable to lithium disilicate. Lithium disilicate: higher resistance than resin ceramics. Higher resistance to fracture for polymer-infiltrated ceramic-network (PICN) than RNCs.
El Ghoul et al 2019	Fracture resistance and failure modes of endocrowns manufactured with different CAD/CAM. (19)	Endocrown/fracture resistance and failure modes	Lithium disilicate glass-ceramic, zirconia-reinforced lithium silicate glass-ceramic, resin nanoceramic	Endocrowns presented higher fracture strength than conventional crowns
Sagsoz et al 2018	In vitro fracture strength and hardness of different computer-aided design/computer-aided manufacturing inlays. (25)	Fracture strength and surface microhardness	Feldspathic ceramic, CEREC blocs; leucite-reinforced ceramic, IPS Empress CAD; resin nanoceramic, 3M ESPE Lava Ultimate; hybrid ceramic, VITA Enamic; and lithium disilicate ceramic, IPS e.max CAD	Lithium disilicate inlays had higher fracture resistance than ceramics.

Egilmez et al 2018	Comparative color and surface parameters of current esthetic restorative CAD/CAM materials. (30)	Inherent color, translucency, surface gloss, surface roughness	Hybrid CAD/CAM blocks (GC Cerasmart); Lava Ultimate; Vita Enamic	Lava Ultimate had the lowest chroma and highest hue. Vita Enamic had the highest chroma and lowest hue.
Kilinc and Turgut 2018	Optical behaviors of esthetic CAD-CAM restorations after different surface finishing and polishing procedures and UV aging: an in vitro study. (31)	Optical properties	Lava Ultimate, Cerasmart, Vita Enamic, Vita Suprinity, and Vita Mark II	Manual polishing for Lava Ultimate, Cerasmart. Glazing for Vita Enamic. For ceramic materials, manual polishing or glazing for color stability.
Wendler et al 2018	Chairside CAD/CAM materials. Part 3: Cyclic fatigue parameters and lifetime predictions. (34)	Cyclic biaxial flexure	Polycrystalline zirconia (IPS e.max ZirCAD), reinforced glasses (Vitablocs Mark II, IPS Empress CAD), glass-ceramics (IPS e.max CAD, Suprinity PC, Celtra Duo), hybrid materials (Enamic, Lava Ultimate)	Susceptibility to subcritical crack growth under cyclic loading was more severe ($n \leq 20$) in lithium-based glass-ceramics and Vitablocs Mark II; nonetheless, it was observed for all materials.
Ludovichetti et al 2018	Wear resistance and abrasiveness of CAD-CAM monolithic materials. (37)	Wear resistance and abrasiveness	IPS e.max CAD (Ivoclar Vivadent AG), Vita Suprinity (Vita Zahnfabrik), Lava Ultimate (3M ESPE), Vita Enamic (Vita Zahnfabrik), and Lava Plus (3M ESPE)	The lowest wear of enamel: Vita Enamic and Lava Ultimate. Lava Plus: the greatest hardness. Nanofilled composite resin and polymer-infiltrated ceramic were more antagonist-friendly.
Belli et al 2017	Chairside CAD/CAM materials. Part 1: Measurement of elastic constants and microstructural characterization. (5)	Young's modulus/Bulk modulus/Poisson's ratio	Polycrystalline zirconia (e.max ZirCAD, Ivoclar-Vivadent), reinforced glasses (Vitablocs Mark II, VITA; Empress CAD, Ivoclar-Vivadent) and glass-ceramics (e.max CAD, Ivoclar-Vivadent; Suprinity, VITA; Celtra Duo, Dentsply), hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE)	Resonant ultrasound spectroscopy showed to be the most complex and reliable method.
Curran et al 2017	Grinding damage assessment for CAD-CAM restorative materials. (26)	Strength	Lithium disilicate glass-ceramic (e.max CAD), leucite glass-ceramic (Empress CAD), feldspar ceramic (VM2; Vita Mark II), feldspar ceramic-resin infiltrated (Enamic), and a composite reinforced with nanoceramics (Lava Ultimate)	Feldspar ceramic-resin infiltrated and nanoceramics were little damaged with no loss of strength.
Wendler et al 2017	Chairside CAD/CAM materials. Part 2: Flexural strength testing. (12)	Ball-on-three-ball (B3B) biaxial strength test	Polycrystalline zirconia (e.max ZirCAD, Ivoclar-Vivadent), reinforced glasses (Vitablocs Mark II, VITA; Empress CAD, Ivoclar-Vivadent) and glass-ceramics (e.max CAD, Ivoclar-Vivadent; Suprinity, VITA; Celtra Duo, Dentsply), hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE)	Strength values ranged from 110.9MPa (Vitablocs Mark II) to 1303.21MPa (e.max ZirCAD)

Egilmez et al 2018	Comparative color and surface parameters of current esthetic restorative CAD/CAM materials. (30)	Inherent color, translucency, surface gloss, surface roughness	Hybrid CAD/CAM blocks (GC Cerasmart); Lava Ultimate; Vita Enamic	Lava Ultimate had the lowest chroma and highest hue. Vita Enamic had the highest chroma and lowest hue.
Kilinc and Turgut 2018	Optical behaviors of esthetic CAD-CAM restorations after different surface finishing and polishing procedures and UV aging: an in vitro study. (31)	Optical properties	Lava Ultimate, Cerasmart, Vita Enamic, Vita Suprinity, and Vita Mark II	Manual polishing for Lava Ultimate, Cerasmart. Glazing for Vita Enamic. For ceramic materials, manual polishing or glazing for color stability.
Wendler et al 2018	Chairside CAD/CAM materials. Part 3: Cyclic fatigue parameters and lifetime predictions. (34)	Cyclic biaxial flexure	Polycrystalline zirconia (IPS e.max ZirCAD), reinforced glasses (Vitablocs Mark II, IPS Empress CAD), glass-ceramics (IPS e.max CAD, Suprinity PC, Celtra Duo), hybrid materials (Enamic, Lava Ultimate)	Susceptibility to subcritical crack growth under cyclic loading was more severe ($n \leq 20$) in lithium-based glass-ceramics and Vitablocs Mark II; nonetheless, it was observed for all materials.
Ludovichetti et al 2018	Wear resistance and abrasiveness of CAD-CAM monolithic materials. (37)	Wear resistance and abrasiveness	IPS e.max CAD (Ivoclar Vivadent AG), Vita Suprinity (Vita Zahnfabrik), Lava Ultimate (3M ESPE), Vita Enamic (Vita Zahnfabrik), and Lava Plus (3M ESPE)	The lowest wear of enamel: Vita Enamic and Lava Ultimate. Lava Plus: the greatest hardness. Nanofilled composite resin and polymer-infiltrated ceramic were more antagonist-friendly.
Belli et al 2017	Chairside CAD/CAM materials. Part 1: Measurement of elastic constants and microstructural characterization. (5)	Young's modulus/Bulk modulus/Poisson's ratio	Polycrystalline zirconia (e.max ZirCAD, Ivoclar-Vivadent), reinforced glasses (Vitablocs Mark II, VITA; Empress CAD, Ivoclar-Vivadent) and glass-ceramics (e.max CAD, Ivoclar-Vivadent; Suprinity, VITA; Celtra Duo, Dentsply), hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE)	Resonant ultrasound spectroscopy showed to be the most complex and reliable method.
Curran et al 2017	Grinding damage assessment for CAD-CAM restorative materials. (26)	Strength	Lithium disilicate glass-ceramic (e.max CAD), leucite glass-ceramic (Empress CAD), feldspar ceramic (VM2; Vita Mark II), feldspar ceramic-resin infiltrated (Enamic), and a composite reinforced with nanoceramics (Lava Ultimate)	Feldspar ceramic-resin infiltrated and nanoceramics were little damaged with no loss of strength.
Wendler et al 2017	Chairside CAD/CAM materials. Part 2: Flexural strength testing. (12)	Ball-on-three-ball (B3B) biaxial strength test	Polycrystalline zirconia (e.max ZirCAD, Ivoclar-Vivadent), reinforced glasses (Vitablocs Mark II, VITA; Empress CAD, Ivoclar-Vivadent) and glass-ceramics (e.max CAD, Ivoclar-Vivadent; Suprinity, VITA; Celtra Duo, Dentsply), hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE)	Strength values ranged from 110.9MPa (Vitablocs Mark II) to 1303.21MPa (e.max ZirCAD)

Fasbinder and Neiva 2016	Surface evaluation of polishing techniques for new resilient CAD/CAM restorative materials. (40)	Surface roughness	Block resin nanoceramic (Lava Ultimate, 3M ESPE), hybrid ceramic (Enamic, Vita), and leucite-reinforced ceramic (EmpressCAD, Ivoclar)	The polished ceramic surfaces were reported smoother than the glazed ceramic surfaces.
Badawy et al 2016	Fracture toughness of chairside CAD/CAM materials - Alternative loading approach for compact tension test. (39)	Fracture toughness	Vita Mark II (Vident) (VMII); Lava-Ultimate (3M/ESPE) (LU); Vita Enamic (Vident) (VE); IPS e.max CAD (Ivoclar Vivadent); crystallized and un-crystallized (E-max and E-max-U)	The highest K_{IC} values were for fired/crystallized glass-ceramicCD (2.65±0.32)/E.max (1.88±0.62). The lowest value was for VMII (0.73 MPa $m^{1/2}$)
Chen et al 2014	The fracture resistance of a CAD/CAM resin nanoceramic (RNC) and a CAD ceramic at different thicknesses. (18)	Fracture resistance	Resin Nano Ceramic (RNC) Polished Lava™ Ultimate CAD/CAM, sandblasted Lava™ Ultimate CAD/CAM, and sandblasted IPS e.max CAD discs	Polished lava had the lowest fracture resistance

Results:

Chairside CAD/CAM materials can be divided into metal alloys, ceramics, resin, and resin-matrix ceramics. There are several brands available for these materials. The indications and the brands of chairside CAD/CAM materials are mentioned in Table 2.

Classification:

1-Metal alloys:

Chrome-cobalt and titanium are available metal blocks in the market. They can be used to fabricate a framework for crowns, fixed partial dentures, and metal ceramics. Titanium blocks can be milled to produce custom-made abutments. However, the lack of aesthetics is their disadvantage.(14) Nowadays, Sintron and Dentsply (Crypton) are available in the market.

2-Ceramics:

There are many classifications for ceramics. Feldspathic, Leucite-reinforced, lithium disilicate reinforced, zirconium oxide, and lithium silicate-reinforced are direct CAD/CAM glass-ceramics. Ceramic restorations have advantages such as excellent aesthetics, favorable milling properties and wear resistance, biocompatibility, and color stability. Their disadvantages include the need for more tooth preparation, brittleness, and wear of the opposing tooth.(11,41)

2-1-Glass-ceramics (silica-based):

Feldspathic: Feldspathic ceramics have two crystallization patterns as a sodium-potassium aluminum silicate peak and potassium-sodium aluminum silicate peak.(2) Due to their high aesthetic properties, they could be used for crowns, partial crowns, and veneers. There are types of blocks for aesthetic anterior restoration consisting of one block with a dentin core and enamel surrounding it. They have been popular for their indication in full-coverage crowns. This restoration could be finished by mechanical polishing and glazing. VITABLOCS Mark II (VITA Zahnfabrik) and CEREC Blocs (Dentsply Sirona) are available blocks in the market.(11)

Fages and colleagues have reported a 98.66% survival rate probability for reinforced feldspathic ceramics for 7 years of clinical service.(42) The long-term survival rate is well documented for CAD/CAM fabricated glass-ceramic restorations as inlays, onlays, and crowns.(2)

2-2-Leucite-reinforced:

Leeson has reported that monolithic crowns can be milled with a highly polished appearance and excellent surface quality.(44)

Fast sintering chairside CAD/CAM zirconia blocks (3M Chairside zirconia and Katana STML) have minimized the sintering time from

Table 2. Examples of chairside CAD/CAM materials

Materials	Products in Market	Indications
Metals	Sintron and Dentsply (Crypton)	Frameworks, metal ceramics
Feldspathic ceramic	VITABLOCS Mark II (VITA Zahnfabrik), CEREC Blocs (Dentsply Sirona)	
	VITABLOCS real life ceramic blocks (VITA), CEREC Blocs c/c In/C pc (Dentsply Sirona), and VITABLOC TriLux Forte (VITA)	Crowns, partial crowns, veneers, endocrowns
Leucite-reinforced ceramics	IPS Empress CAD (Ivoclar Vivadent)	Anterior veneers
Lithium silicate/disilicate ceramics	IPS e.max CAD (Ivoclar Vivadent)	Monolithic crowns, anterior veneers, ultrathin veneers, inlays and onlays, endocrowns, implant restoration
Oxide ceramics	CEREC Zirconia (Dentsply Sirona), Katana Zirconia Block (Kuraray Noritake Dental, Inc.), VITA YZ (VITA Zahnfabrik), Lava Zirconia Block (3M ESPE), Zirconia meso (Dentsply Sirona): VITA SUPRINITY PC (VITA Zahnfabrik) Celtra Duo (Dentsply Sirona), inCorisTZI (Dentsply Sirona), and IPS e.max ZirCAD (Ivoclar Vivadent).	Full coverage restorations, crowns, and bridges
PMMA (polymethyl methacrylate)	Cerec guide bloc/inCoris PMMA (Dentsply Sirona) Telio CAD (Ivoclar Vivadent) VITA CAD-Temp mono colors/ multi colors Blocks (VITA Zahnfabrik) VITA CAD-Waxx™ blocks (VITA North America), artBloc Temp (Merz Dental), and Sintodent (Sentis)	Temporary restorations (veneers, crowns, bridges, and inlay/onlay)
Resin composites	Paradigm MZ100 (3M ESPE), Tetric CAD (Ivoclar Vivadent), CAD Temp mono/multicolor (Vita) and BRILLIANT Crios (Coltene) Filtek Ultimate (3M ESPE)	Temporary restorations: veneers, inlay/onlay, anterior/posterior crowns, and bridges
Nanoceramics	Ultimate (Lava), Cerasmart (GC), Shofu Block HC, and Ambarino high class (Creamed)	Anterior/posterior single crowns and bridges (bridges with small extent)
PICN (polymer-infiltrated ceramic network)	VITA Enamic	Veneers, inlay/onlay, and anterior/posterior single crowns
Resin-based ceramics	Cerasmart (GC), Grandio Blocs (VOCO), LAVA Ultimate (3M ESPE), BRILLIANT Crios (Coltene), HC Block CAD/CAM Ceramic-based restorative (Shofu) and KATANA AVENCIA block (Kuraray Noritake Dental Inc.)	
Hybrid ceramics	VITA ENAMIC (VITA Zahnfabrik)	

Figure2:Examples of In Lab and chairside CAD-CAM materials.

but a high Weibull modulus(16.10), according to the manufacturer.

Feldspathic and leucite-reinforced ceramics have great translucency. In optical properties, they are superior to other dental ceramics while they cannot be used for hiding metal-inlay cores. In addition, they are not adequate against occlusal stress.(11,14)

2-3-Lithium silicate/disilicate ceramics:

Lithium silicate has been indicated for monolithic crowns, inlays, and onlays. Their biaxial flexural strength (407 MPa) has made them the strongest silica-based ceramics.(11)

IPS e.max CAD (Ivoclar Vivadent) and lithium silicate/phosphate glass-ceramics have been recently introduced to the market.

CAD/CAM LDS crowns show satisfactory clinical outcomes for chairside manufacturing.[2]
Lithium disilicate has favorable translucency and shade variety. It is indicated for implant restoration and anterior/posterior fixed dental prostheses (FDPs).

IPS e.max CAD (Ivoclar Vivadent) is the available block in the market.Aziz and colleagues reported no chipping or fracture in a 4-year clinical study. Lithium disilicate glass-ceramic crowns exhibited a high survival rate (95%).

In addition, patients and clinicians rated the aesthetics as excellent.[43]

2-4-Oxide ceramics:

They have been used for their excellent mechanical properties (high flexural strength against masticatory forces). They can be indicated for full coverage restorations. They should be air-particle abraded by alumina or silica-coated alumina.[2]

The new generation of zirconia has represented great light transmission but the first generation had limited translucency. There are high translucent blocks available in the market, such as CEREC Zirconia (Dentsply Sirona), Katana Zirconia Block (Kuraray Noritake Dental Inc.), and VITA YZ (VITA Zahnfabrik).

Leeson has reported that monolithic crowns can be milled with a highly polished appearance and excellent surface quality.[44]

Fast sintering chairside CAD/CAM zirconia blocks (3M Chairside zirconia and Katana STML) have minimized the sintering time from the traditional 8 hours to 20 minutes.[45]

3-Resin:

Resin-based materials have several advantages such as easy polishing and high fatigue resistance.[11] There are four types available in the market: PMMA, resin-composites, nanoceramics, and PICN (polymer-infiltrated ceramic network).

3-1-PMMA (polymethyl methacrylate)

The thermoplastic polymer is transparent. PMMA decreases the milling time. Also, lack of fillers leads to low mechanical strength. These are used for temporary restorations (veneers, crowns, bridges, and inlays/onlays) from 6 months to one year.[14] Cerec guide bloc/inCoris PMMA (Dentsply Sirona), Telio CAD (Ivoclar Vivadent), and VITA CAD-Temp mono colors/multi colors Blocks (VITA Zahnfabrik) are examples of available PMMA blocks in the market.[11]

3-2-Resin composites:

They are composed of a monomer matrix resin with fillers. They are easy to use and have great fatigue resistance.[14] The polymerization of composite resins is never complete. Paradigm MZ100 (3M ESPE), Tetric CAD (Ivoclar Vivadent), and CAD Temp mono/multicolor (Vita) blocks are available for chairside CAD/CAM for temporary restorations for up to 3 years with greater mechanical resistance than PMMA. They could be used for veneers, inlay/onlay, and anterior/posterior crowns and bridges.[2,5] It has been reported that chairside light-curing CAD/CAM resin-based composites are practicable and can be recommended for both experienced and inexperienced users.[46]

3-3-Nanoceramics:

They have fillers smaller than 100nm. They have characteristics similar to the natural teeth in terms of flexure, compression, and abrasion. Their bonding ability is excellent but their optical properties are medium. They are indicated for anterior/posterior single crowns and bridges (bridges with small extent). Ultimate (Lava) and Cerasmart (GC) are examples of available blocks in the market.[2,4,14,47]. Note that these are new materials, and their biocompatibility is still questionable due to their monomer release.

3-4-High-performance polymers (HPP)

These are a group of hybrid materials. HPPs are heavily nanocomposite filled and polymerized under high pressure and temperature. They had been reported better machinability, higher flexural strength, modulus of resilience, and smoother milled margins in comparison to ceramics.[6,16] This material presents very good biocompatibility, a high temperature resistance, chemical inertness, good mechanical properties, good polishability, low plaque attachment, and good bond strength with veneering composites and cements. PEEK has a low modulus of elasticity in comparison to zirconium oxide and metal alloys. PEEK provides a reduction of stresses transferred to dental structures. Although PEEK is frequently used in dental clinical practice, only a few studies are available on the application of this material to digital dentistry.[48-52]

4-Resin-matrix ceramics (RMC):
These materials have two phases of polymer and ceramic with different structures. They are categorized as follows:
4-1-Resin-based ceramics:

They have the combined advantages of polymers and ceramics, which result in superior aesthetics and strength. They can be glazed. Cerasmart (GC), Grandio Blocs (VOCO), LAVA Ultimate (3M ESPE), and KATANA AVENCIA block (Kuraray Noritake Dental, Inc.) are available blocks in the market.[2,11]
4-2-Hybrid ceramics:

These could be milled in their ultimate form and allow quicker manufacturing. The IPN (ceramic-based resin interpenetrating) is composed of a feldspathic ceramic and acrylic polymer.[6] Hybrid ceramic chairside blocks have shown better machinability and smoother milled margins. They are available as VITA ENAMIC (VITA Zahnfabrik) in the market.[2]

4-3-PICN (polymer-infiltrated ceramic network):
The PICN combines the properties of polymers and ceramics. VITA Enamic is available in the market. This material has similar abrasion, high flexural strength, and elasticity near to dentin with high bonding ability, although its optical properties are medium, and there is a lack of shade range.[14] The PICN could be indicated for veneers, inlays/onlays, and anterior/posterior single crowns. It has been reported that the PICN has better wear resistance compared to composite resins.[2,5]

Digital workflow:
CAD/CAM procedures consist of extraoral scanning of a stone cast or intraoral scanning, software that processes the stereolithography (STL) file and designs the restoration, and a fabrication system (subtractive or additive system). The STL file can be transferred to the laboratory. There are other file formats as PLY, DCM, and UDX.[11] This time-efficient process allows single appointment treatment. There are several CAD/CAM software programs available in the market, such as 3Shape Dental system, FreeForm, Exocad, Polywork, Dental wings (DWOS), and Digistell. Not all milling machines are able to mill and grind all types of restorative materials. There are millable materials as wax, metals, PMMA, hybrid ceramics, composite resins, high-performance polymers, polycrystalline ceramics, and resin-based ceramics. Additive manufacturing (3D printing) has been used for the fabrication of surgical guides, temporary restorations, occlusal splints, bite guards, scaffolds, and orthodontic appliances. Also, composites, metals, resins, and ceramics can be indicated for 3D printing.[45] It should be considered that material selection depends on the type of milling machine. Not all milling machines allow both dry milling and wet milling. Zirconia blocks should be dry milled but silica-based zirconia should be wet-milled.[11]

There are different chairside CAD/CAM systems available in the market. Zaruba and Mehl have listed these systems as follows: CS 3500, CS 3600, CS 3000 (Carestream Dental, Rochester, NY, USA), Cerec Omnicam, Cerec MC, X, XL (Dentsply Sirona, York, PA, USA), DWIO, DWLM (Dental Wings, Montreal, Canada), myCrown Scan, myCrown Mill (Fona Dental, Bratislava, Slovakia), PlanScan, Emerald, PlanMill (Planmeca, Helsinki, Finland), IntraScan, Inhouse5x wet, and dry (Zfx, Dachau, Germany). Also, Chairside cooperation partners, such as Trios 3 Wireless (3Shape, Copenhagen, Denmark), PrograMill One (Ivoclar Vivadent, Schaan, Liechtenstein), Lyra Mill (Lyra, Paris, France), and CARES® C series (Straumann, Basel, Switzerland).[3]

An increasing number of CAD/CAM materials and systems are now accessible. As a result, choosing the best chairside CAD/CAM material for each situation has become more challenging.[2] Chairside CAD/CAM systems use an intraoral scanner, software, and subtractive or additive manufacturing.[10]

Resin composites have shown a lower modulus of elasticity in comparison to ceramics. The flexural strengths after glazing of lithium disilicate (360±60MPa) and ZLS (370MPa) were reported to be in a similar range, whereas polished ZLS ceramics feature higher translucency. ZLS ceramics consist of a glass matrix with 10% dissolved zirconia.[53] Matzinger et al reported that ceramics had the lowest wear, followed by resin-infiltrated materials and resin composites.[53]

Al-Harbi and colleagues conducted an in-vitro study to evaluate the flexural strength, surface roughness, and surface hardness of resin nanoceramics (LAVA Ultimate) and leucite-reinforced VITA block mark II. The three aging processes included mechanical cycling (80 N), thermal cycling, and water. After aging, the surface roughness of nanoceramics was found to be comparable to that of leucite. They reported that leucite had higher surface hardness, and nanoceramics displayed higher flexural strength and surface roughness.(7)

Bankoğlu Güngör and Karakoca Nemli have evaluated the fracture resistance of chairside CAD/CAM monolithic ceramic and veneered zirconia molar crowns after thermomechanical aging and reported that the highest fracture resistance was observed for yttria-stabilized zirconia crowns followed by lithium disilicate.(54)

Wendler and colleagues examined the elastic constants, microstructural characterization, cyclic fatigue, lifetime, and flexural strength of polycrystalline zirconia, including e.max ZirCAD (Ivoclar Vivadent), reinforced glasses (Vitablocs Mark II, VITA; Empress CAD, Ivoclar Vivadent), glass-ceramics (e.max CAD, Ivoclar Vivadent; Suprinity, VITA; Celtra Duo, Dentsply) and hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE). They reported the strength of Vitablocs Mark II and e.max ZirCAD to be 110.9 MPa and 1303.21 MPa, respectively. The Young's modulus was reported to be 10.9 for Lava Ultimate and 201.4 for e.max ZirCAD. The Poisson's ratio was reported to be 0.173 for Empress CAD and 0.47 for Lava Ultimate. More crack growths under cyclic loading were observed in lithium-based glass-ceramics and Vitablocs Mark II in comparison to other brands.(5,12,34)

Furtado de Mendonca et al conducted an in-vitro study to examine the microstructure, elastic modulus, fracture strength, and microhardness of lithium disilicate (IPS e.max, CAD), zirconia reinforced lithium silicate (VITA Suprinity), hybrid high-performance polymer (HPP) composite resin (GC Cerasmart), and hybrid polymer-infiltrated ceramic network (VITA Enamic) in the full crown of mandibular first molars. They reported that chairside materials are suitable for posterior full crown restorations. Hybrid materials exhibited lower hardness and stiffness compared to glass-ceramics. Chippings were more common in hybrid materials.(6)

Gul and Altınok-Uygun assessed the repair bond strength of nanohybrid resin composite blocks (Lava Ultimate, Cerasmart, and Vitablocs Mark II). They described that the lowest values were observed in the Vitablocs Mark II group ($P<0.05$). The Cimara System, Porcelain Repair, and Clearfil Repair showed significantly higher bond strength compared to other systems. They concluded that resin nanoceramics are more successful in intraoral repair applications.(22)

Bahadır and Bayraktar assessed the color stability and microtensile bond strength of Lava Ultimate, Vita Enamic, and nanofill composite resin. They reported the highest value (20.818 MPa) for non-thermocycled, bur-ground, silane-applied Vita Enamic. They stated that composite resin specimens showed more staining than the blocks ($P<0.05$). The authors recommended the use of silane in the repair process.(29)
Sismanoglu et al evaluated the reparability of Brilliant Crios, Lava Ultimate, Shofu Block HC, and Vita Enamic blocks. They reported the highest mean bond strength for Vita Enamic.(35)

According to Matzinger and colleagues, ceramics exhibited lower mean wear compared to resin composites. They evaluated different polishing procedures on labside and chairside resin-based composites, resin infiltrated ceramics, zirconia-reinforced lithium silicate, and lithium disilicate glass-ceramics. They found no significant differences in the roughness after labside and chairside polishing. The difference in the results may be explained by different filler compositions, material properties, and topography.(53)
High-density materials, such as ceramics based on lithium disilicate or feldspar, have shown the best color stability.(28) Crystalized glass-ceramics (CD/E-max) and Vita Mark II have shown the highest and lowest fracture toughness, respectively.

Fasbinder and colleagues reported that adhesive retention with total-etch or self-etch cementation resulted in similar clinical outcomes. Resilient ceramic onlays had a lower incidence of fracture than leucite-reinforced ceramic onlays, nanoceramics, and glass-ceramics.(4) Gul and Altınok-Uygun reported that Cimara, Porcelain Repair, and Clearfil Repair systems significantly increased the bond strength of nanohybrid resin composite for CAD/CAM blocks.(22)

Gasparik and colleagues showed that lithium disilicate or feldspar-based ceramics are highly dense materials with superior color stability. Hybrid ceramics showed color differences be-low the perceptible threshold. Composite-based materials showed lower color stability for their increased organic matrix.(28) Kanat-Ertürk reported that glazing rendered higher color stability than mechanical polishing, external staining, and glaze surface finishing. Polishing pastes decreased discoloration.(27)

Zirconia showed less volumetric loss than lithium disilicate and leucite.(36) Dursun and colleagues concluded that chairside CAD/CAM restorations are minimally invasive treatment options with high strength, biocompatibility, and aesthetics. They cause no gingival trauma and are easy to execute with a high patient satisfaction rate.(55)

Fages et al have concluded that reinforced feldspathic ceramics have a very respectable clinical outcome in endocrowns.(42)

Nejatidanesh and colleagues have reported that chairside CAD/CAM ceramic laminate veneers (Empress CAD and e.max) were clinically successful with a mean survival rate of 99.0% and success rate of 96.4% after 5 years.(56) However, Magne et al have reported that posterior veneers made of composite resin (Paradigm MZ100) had significantly higher fatigue resistance (P<0.002) compared to IPS Empress CAD and IPS e.max CAD.(57)

Ahn and colleagues compared chairside CAD/CAM and labside CAD/CAM and reported that both CAD/CAM systems showed a proper fit that could be used clinically.(10)

Overall, heat-pressed lithium disilicate restorations have a better marginal fit in comparison to other CAD/CAM restorations.(45)

Chairside procedures have improved patient satisfaction by reducing the cost, clinical procedures, number of appointments, and treatment time. Intraoral scanning has simplified the treatment for patients with limited mouth opening or strong gag reflex. It has been reported that the chairside CAD/CAM system using intraoral scanning is at least as accurate as the conventional method.(3)

Currently, the digital approach is being implemented worldwide. It has emerged into a patient/clinician-friendly procedure. It should be considered that milling machines and 3D printers have become smaller. In addition, there are several updated design software programs. Many modern laboratory materials can be also fabricated using the chairside procedure. Clinicians should choose the chairside materials according to their work habits and material properties.

Conclusion:

Based on the findings of this study, the following conclusions were drawn:

1) Chairside CAD/CAM restorations are fast, reliable, predictable, effective, patient-friendly, and cost-effective treatment options. Design software and intraoral scanners have made the treatment procedure simple. Chairside individualization of dental restorations could help improve patient satisfaction.

2) Different blocks are available in the market that allow the fabrication of all types of restorations and prosthetic reconstruction. However, there is no material for universal applications with ideal clinical outcomes and properties.

3) There are limited long-term clinical data and clinical experience on modern materials. Hence, future studies need to address the long-term clinical performance of chairside CAD/CAM materials.

Acknowledgements:

The Faculty of Dentistry of Islamic Azad University of Medical Sciences, Tehran, Iran, has supported this work.

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Cites this paper as: Eskandarion S, Neshandar M, Rokhshad R. Classifications and Properties of Materials for Chairside Computer-Aided Design/Computer-Aided Manufacturing Dentistry: A Review. J Res Dent Maxillofac Sci. 2021;6(2):36-50.