Universidad
Europea

TRABAJO DE FIN DE GRADO

Grado en Odontología

CERÁMICAS EN RESTAURACIONES PROTÉSICAS CON TECNOLOGÍA CAD-CAM

Madrid, curso 2020/2021

Número identificativo: 79

Resumen

Introducción: Desde la introducción del CAD-CAM en odontología en 1971, se habla del concepto de *workflow* digital. Hoy día, gracias a los enormes avances tecnológicos, disponemos de sistemas "*in-office*", también conocidos como *chairside*, que, juntos a materiales cerámicos en continua transformación, nos permiten proporcionar restauraciones protésicas de elevada calidad. Se puede decir que las porcelanas dentales ya han reemplazado a la metal-cerámica, debido al aumento de demanda de prótesis altamente estéticas y biocompatibles. Asimismo se ha incrementado la producción *chairside* de reconstrucciones monolíticas, las cuales, cada vez mas, presentan propiedades similares a las multicapas. **Objetivos:** El objetivo del estudio consistió en la investigación de las cerámicas dentales CAD-CAM. **Metodología:** La presente investigación se realizó en base a una extensa revisión bibliográfica, utilizando Medline, Pubmed y la biblioteca online de la Universidad Europea. Además se visitó la página web de cada casa comercial para identificar sus materiales cerámicos. **Conclusión:** Las porcelanas CAD-CAM disponibles hoy día para sector anterior son las feldespáticas puras y reforzadas con leucita / circonia, el silicato de litio reforzado con circonia y el disilicato de litio. Mientras que para sectores posteriores encontramos especialmente el óxido de circonio y las nanocerámicas. Las restauraciones monolíticas a menudo se utilizan mas, sin igualar todavía a igualar la estética de las multicapas. Las investigaciones han demostrado resultados muy prometedores, pero aún son necesarios mas estudios para que éstas lleguen a ser la primera opción terapéutica.

Palabras clave: cerámicas dentales, CAD-CAM, odontología protésica, prótesis, restauraciones protésicas, rehabilitación digital.

Abstract

Introduction: Since the introduction of CAD-CAM in dentistry in 1971, has been introduced the concept of digital workflow. Today, thanks to enormous technological advances, we have “in-office” systems, also known as chairside, that, side by side with constantly innovated ceramic materials, allow us to provide high-quality prosthetic restorations. It can be said that dental porcelains have already replaced metal-ceramic, due to the increase in demand for highly aesthetic and biocompatible prostheses. Likewise, the chairside production of monolithic reconstructions has increased, which, more and more, have properties similar to multilayers ones. **Objectives:** The aim of this research was to investigate dental CAD-CAM ceramics. **Methodology:** The present research was carried out based on an extensive bibliographical review, using Medline, Pubmed and the online library of Universidad Europea. In addition, the website of each commercial house was visited to identify their ceramic materials. **Conclusion:** The CAD-CAM porcelains available today for the anterior sector are the pure feldspathic and reinforced with leucite / zirconia, the lithium silicate reinforced with zirconia and the lithium disilicate. While for posteriors sectors we find especially zirconium oxide and nanoceramics. Monolithic restorations are used more frequently, not yet reaching the same level of aesthetics as multilayers. Research has shown very promising results, but further studies are needed for these to become the first therapeutic option. **Keywords:** dental ceramics, CAD-CAM, prosthetic dentistry, prosthodontics, prosthetic restorations, digital rehabilitation.

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ATZ	*Alumina-toughened zirconia*
ASTM	*American Society for Testing and Materials*
CAD-CAM	*Computer-aided design - Computer-aided manufacturing*
CIP	*Cold isostatic pressed*
Ej.	Ejemplo
GPa	Gigapascal - *Biaxial flexural modulus*
HT	*High translucent*
HTML	*Highly translucent multi layered*
IPS	*Ivoclar porcelain system*
LT	*Low translucent*
ME	*Material extrusion*

MJ	*Material jetting*
MO	*Moderate opacity*
MPa	Megapascal - *Biaxial flexural strength*
MT	*Moderate translucent*
PBF	*Powder base fusion*
PICN	*Polymer-Infiltred Ceramic Network*
PSZ	*Partially stabilized zirconia*
SLA	*Stereolithography*
ST	*Super translucent*
STL	*Streolitography / Standard triangle language*
STML	*Super translucent multi layered*
TZP	*Tetragonal zirconia polycrystals*
UHT	*Ultra high translucent*
UTML	*Ultra translucent multi layered*
XT	*Extra translucent*
YZ	*Yttria zirconia*
Y-PSZ	*Partially stabilized zirconia with yttria*
Y-TZP	*Tetragonal zirconia polycrystals with yttria*
ZTA	*Zirconia-toughened alumina*
3D	*Tri-Dimensional*

Introducción

Todos los dentistas conocen la enorme labor que está detrás de cada restauración protésica. Empezando por la impresión de un diente tallado, se obtiene un modelo en escayola desde el cual se podrá realizar la restauración deseada. Debido al importante trabajo manual que conllevan los métodos de fabricación tradicionales, se requiere mucho tiempo y pueden introducir errores en el resultado final. (1, 2)

Siguiendo los avances robóticos y tecnológicos, toda rama de la medicina se ha adaptado a utilizar maquinas y *software* para tratar de agilizar los tiempos y mejorar los tratamientos. Por eso en 1971 se introdujo en odontología la tecnología CAD-CAM (*computer-aided design* - *computer-aided manufacturing*). Se descubrió que era posible efectuar clásicos procedimientos manuales a través de ordenadores, eso sí con la ayuda de varios ingenieros informáticos y horas de diseño electrónico. Sucesivamente Heitlinger y Rodder en 1979 y Mörmann y Brandestini en 1980, amplían los estudios acerca de este campo. (1, 3)

En estas épocas de revolución tecnológica también se pudo ver el incremento simultáneo de los materiales cerámicos disponibles. Según sus composiciones se diferencian en varias tipologías, con la finalidad de restaurar todo tipo de situación clínica: con matriz vítrea para zonas mas estéticas, policristalinas (que no contienen fase vítrea) como estructura interna por sus mejores propiedades mecánicas o con matriz de resina para solucionar problemas de fragilidad. (2)

Gracias a los años de investigación y ensayos acerca del CAD-CAM en odontología, se ha demostrado su enorme aporte, tanto para los técnicos como para los clínicos. Los sorprendentes avances en dicha área no sólo permiten ahorrar materiales (alginato, silicona, escayola, ceras, etc.) y tiempo, si no que también se obtienen mejores detalles de las restauraciones protésicas. (2)

Pensar lo mucho que ha evolucionado esta tecnología puesto que el primer prototipo de prótesis dental CAD-CAM de la historia fue desarrollada por Duret en 1983. En noviembre del ’85, en el congreso de la *Association dentaire française* (ADF) mostró su sistema creando, en menos de una hora, una corona posterior para su mujer. (1, 3)

Por medio de escáneres intraorales ya no nos hace falta tomar impresiones tradicionales. En pocos minutos se obtiene un modelo virtual (3D) en formato STL (*Streolitography / Standard triangle language*) en el ordenador, donde se puede planificar la restauración, elegir el material mas apto y con un click tenerlo listo en menos de una hora directamente en la consulta (*chairside*). Este procedimiento es un flujo totalmente digital (*digital workflow*) mas comúnmente conocido como “*chairside*” es decir elaborado “*in-office*” en la misma clínica dental, en tiempos considerablemente reducidos, normalmente en una única cita. (3, 4)

Obviamente esto no será posible en cualquier circunstancia, de todos modos el hecho de tener bibliotecas digitales con todos los materiales que se pueden utilizar ha revolucionado el modo de trabajar de los odontólogos y de los técnicos. (1, 2)

Las opciones disponibles para la fabricación CAM son fundamentalmente dos: producción por sustracción o por adicción. (5) La primera, y mas comúnmente utilizada, se lleva a cabo a través el fresado de un bloque (Figura 1) o disco de cerámica previsto de un especial mango para su sujeción, específico para cada tipo de fresadora (Figura 2). (6)

Mientras que la fabricación aditiva es el proceso de oposición de materiales capa por capa, normalmente a través de una impresora 3D (Figura 3). La Sociedad Estadounidense de Pruebas y Materiales (*American Society for Testing and Materials*, ASTM) la ha clasificado en siete diferentes tecnologías: estereolitografía (SLA), inyección de material (MJ), extrusión de material

(ME), inyección de aglutinante (BJ), fusión a base de polvo (PBF), estratificación de hojas (SL) y deposición de energía directa (DEP). (10, 11)

Figura 1. Bloques cerámicos para fabricación sustractiva CAM (7)

Figura 2. Fresadora CEREC MC X2 (Dentsply Sirona, York, Pensilvania, EE.UU.) (8)

Figura 3. Dos tipos de impresoras 3D (de izquierda a derecha: NewPro 3D, Vancouver, Canada; Formlabs, Somerville, Massachusetts, EE.UU.) (9)

Será muy importante la selección del material cerámico y, puesto que hoy en día disponemos de amplias alternativas, hay que conocer atentamente las características de cada uno de ellos para conseguir un resultado clínico cuanto más predecible.

Ya ha pasado la época de la metal-cerámica, considerada el *gold-standard* por sus resultados y por haber sido la mas estudiada e investigada. Ahora hay total confiabilidad en las cerámicas integrales, debido a que han mejorado desde que vieron su *incipit* con las porcelanas aluminosas por John McLean en 1965. (12)

Con la introducción de la circonia cada vez se habla menos de la alúmina. El óxido de circonio es un material muy resistente, que a lo mejor deja pasar poca luz, pero apto a cubrir todos los roles de la restauradora, desde la corona unitaria anterior, hasta la posterior, asimismo puentes extensos y eventuales pilares implantares. (2, 12) Por otro lado está el disilicato de litio, un material extremadamente dúctil, excelente desde el punto de vista estético especialmente en el sector anterior, pero utilizable sobre todo para restauraciones unitarias. (12)

Debido al aumento de demanda por parte de los pacientes de restauraciones sin metal, biocompatibles, mas resistentes y sobre todo más miméticas, se vio el incremento de materiales que respetaban estas características. (13, 14) Contemporáneamente al gran número de cerámicas que se sacaron a la venta, salieron artículos de investigación sobre éstas y a la vez varias clasificaciones. Según el artículo de Gracis et al. (12) "*A new classification system for all-ceramic and ceramic-like restorative materials*" (2015), teóricamente, se tendría que utilizar un sistema de taxonomía para decisiones clínicas pertinentes a los siguientes aspectos: sitio de empleo del material (anterior *vs.* posterior), tipo de restauración (parcial *vs.* total, tramo corto *vs.* tramo largo), tipo de cementado (tradicional *vs.* adhesivo).

Por ejemplo, una clasificación ampliamente utilizada es la de Kelly y Benetti (14) que ordena las cerámicas según el contenido de vidrio: *(1)* materiales predominantemente vítreos, *(2)* vidrios llenos de partículas (y cerámicas vítreas) y *(3)* cerámicas policristalinas en las que no hay vidrio. (12) Mientras que la clasificación de Gracis (12) se estructura de la siguiente forma:

(1) Cerámicas de matriz vítrea: (1.1) feldespáticas (ej. CEREC Blocs C, Dentsply Sirona; de leucita IPS Empress CAD, Ivoclar Vivadent), (1.2) sintéticas (ej. de disilicato de litio IPS e.max CAD, Ivoclar Vivadent), (1.3) laminado de vidrio (ej. de alumina In-Ceram Alumina, VITA Zahnfabrik).

(2) Cerámicas policristalinas: (2.1) alumina (ej. Procera AllCeram, Nobel Biocare), (2.2) circonia estabilizada (ej. NobelProcera Zirconia, Nobel Biocare), (2.3) alumina endurecida con circonia (ZTA), (2.3) circonia endurecida con alumina (ATZ).

(3) Cerámicas de matriz de resina: (3.1) resinas nanocerámicas (ej. Lava Ultimate, 3M ESPE), (3.2) nanocerámicas con resina (ej. VITA ENAMIC, VITA Zahnfabrik), (3.3) cerámicas de circonia-silice en matriz interpenetrante de resina.

Otras clasificaciones no incluyen a las nanocerámicas, como es el caso de las reportadas por Butt et al. (15) y Galante et al. (16). De todos modos éstas se reconocen como porcelanas no obstante una parte de su composición lleve composite. (12, 14, 17)

Con respecto a los diferentes materiales cerámicas CAD-CAM encontramos la taxonomía de Sulaiman (17) de 2020. En ella se describen las porcelanas de la siguiente forma: *(1)* Cerámicas / resinas infiltradas (cerámicas híbridas): (1.1) matriz de polímero infiltrada con partículas de relleno cerámico (ej. Lava Ultimate, 3M ESPE), (1.2) red cerámicas infiltrada con un polímero (ej. VITA

ENAMIC, VITA Zahnfabrik); *(2)* Cerámicas de silicato: (2.1) feldespática, (2.2) reforzada con leucita, (2.3) disilicato de litio; *(3)* Cerámicas de óxido o policristalinas: (3.1) óxido de aluminio, (3.2) óxido de circonio (3 mol% de policristales de circonia tetragonal con itrio (3Y-TZP), 4 mol% de circonia parcialmente estabilizado con itrio (4Y-PSZ), 5 mol% de circonia parcialmente estabilizado con itrio (5Y-PSZ)).

Puesto que la mayoría de clasificaciones incluyen a porcelanas de matriz vítrea, policristalinas y matriz de resina, el siguiente estudio tratará acerca de todas ellas.

Las cerámicas mas utilizadas en odontología con tecnología CAD-CAM

Desde la revisión de 7 artículos (2, 12-17) ha sido posible identificar las principales porcelanas para restauraciones protésicas moldeables tramite tecnología CAD-CAM.

Las cerámicas de matriz vítrea se dividen según su composición. Pueden llevar mayor concentración de leucita como por ejemplo *Ivoclar Porcelain System* (IPS) Empress CAD (Ivoclar Vivadent, Liechtenstein) o contener disilicato de litio como IPS e.max CAD (Ivoclar Vivadent). Otras se componen de silicato de litio reforzado con circonia (ej. VITA SUPRINITY PC, VITA Zahnfabrik, Alemania; Celtra Duo, Dentsply Sirona, EE.UU.). (2, 12, 14-17)

En contraposición encontramos las porcelanas policristalinas que actualmente llevan casi todas óxido de circonio (mas comúnmente conocido como circonia o circona), por ejemplo: InCoris ZI (Dentsply Sirona), Initial Zirconia Disk (GC Europe, Bélgica), IPS e.max ZirCAD (Ivoclar Vivadent), Katana Zirconia Block (Kuraray Noritake, Japón), NobelProcera Zirconia (Nobel Biocare, Suiza), VITA YZ (VITA Zahnfabrik, Alemania), Lava Plus Zirconia (3M ESPE, EE.UU.). (2, 12, 14-17) Las predominantemente aluminosas (ej. Procera AllCeram, Nobel Biocare;

In-Ceram AL, VITA Zahnfabrik), hoy día prácticamente ya no se utilizan debido al aumento de popularidad de las circoniosas. (2, 12, 15)

Con respecto a las porcelanas de matriz de resina encontramos tanto nanocerámicas (ej. Katana Avencia Block, Kuraray Noritake; VITA ENAMIC, VITA Zanhfabrik) como cerámicas híbridas (ej. SHOFU Block HC, SHOFU Dental GmbH; Lava Ultimate, 3M ESPE). (12, 14-17) Se diferencian dependiendo de su composición, no obstante esto para generalizar se pueden llamar tanto de una como de la otra forma. (17)

Después del análisis de estos 7 artículos (2, 12-17) se han apuntado las principales casas comerciales que proporcionan cerámicas al mundo de la odontología digital y junto a ellas los tipos de porcelanas CAD-CAM que comercializan en la actualidad (Tabla 1). La clasificación utilizada es la de Gracis (12).

Tabla 1: principales casas comerciales y las cerámicas CAD-CAM que comercializan.

CASA COMERCIAL	(1) Matriz vítrea	(2) Policristalinas	(3) Matriz de resina
Dentsply Sirona, York, Pensilvania, EE.UU. (18)	- Feldespática (CEREC Blocs C)* - Estratificación policromática (CEREC Blocs C PC)* - Vidrio de silicato (CEREC Blocs C In)* - Disilicato de litio reforzado con circonia (Celtra Duo)*	- Circonia translúcido precoloreado (Cercon, CEREC Zirconia*, CEREC Zirconia meso*, inCoris TZI C*) - Circonia translúcido (inCoris TZI)* - Circonia (inCoris ZI)*	NP

Tabla 1: principales casas comerciales y las cerámicas CAD-CAM que comercializan.			
CASA COMERCIAL	**(1) Matriz vítrea**	**(2) Policristalinas**	**(3) Matriz de resina**
GC Europe, Leuven, Bélgica (19)	Feldespato reforzado con leucita (Initial LRF Block)*	Circonia (Initial Zirconia Disk)	Nanocerámica (CERASMART, CERASMART270)*
Ivoclar Vivadent, Schaan, Liechtenstein (20)	- Disilicato de litio (IPS e.max CAD)* - Feldespato reforzado con leucita (IPS Empress CAD)*	Circonia (IPS e.max ZirCAD)*	NP
Merz dental GmbH, Lütjenburg, Alemania (21)	NP	- Circonia (M-ZR multilayer HT, M-ZR multilayer HT+, M-ZR multicolor ST, M-ZR color HT, M-ZR white HT)	NP
Kuraray Noritake, Kurashiki, Japón (22)	NP	- Circonia (Katana Zirconia Block)* - Circonia (Katana Zirconia)	Nanocerámica (Katana Avencia Block)*
Nobel Biocare, Zurigo, Suiza (23)	NP	Circonia tetragonal estabilizada con itrio (NobelProcera Zirconia, Nacera Pearl Shaded)	NP
SHOFU Dental GmbH, Ratingen, Alemania (24)	NP	Circonia de alta translucidez (SHOFU Disk ZR Lucent)	- Cerámica híbrida (SHOFU Block HC)* - Cerámica híbrida (SHOFU Disk HC)

Tabla 1: principales casas comerciales y las cerámicas CAD-CAM que comercializan.

CASA COMERCIAL	**(1) Matriz vítrea**	**(2) Policristalinas**	**(3) Matriz de resina**
VITA Zahnfabrik, Bad Säckingen, Alemania (25)	- Feldespática (VITABLOCS Mark II)* - Estratificación policromática (VITABLOCS TriLuxe forte, VITABLOCS RealLife)* - Disilicato de litio reforzado con circonia (VITA SUPRINITY PC)	Circonia (VITA YZ)*	Nanocerámica (VITA ENAMIC*, VITA ENAMIC IS, VITA ENAMIC multiColor)
3M ESPE, St. Paul, Minesota, EE.UU. (26)	NP	- Circonia (Lava Plus HT Zirconia Disc, Lava Zirconia Blocks*) - Circonia fluorescente (3M Lava Esthetic Fluorescent Full-Contour Zirconia Disc) - Circonia (3M Chairside Zirconia)*	Cerámica híbrida (Lava Ultimate)*

Abreviatura: NP (no produce)
* Disponible para *chairside*

Objetivos

- Objetivo principal:

- Investigar las cerámicas que se procesan con tecnología CAD-CAM disponibles hoy en día para restauraciones protésicas: indicaciones, ventajas, desventajas.

- Objetivos secundarios:

- Exponer las indicaciones de las cerámicas CAD-CAM y explicar sus ventajas y desventajas.
- Comparar el uso de las cerámicas dentales CAD-CAM: monolíticas *vs.* estratificadas.
- Indicar todas las porcelanas CAD-CAM fabricadas por las distintas casas comerciales, sus indicaciones y ventajas.

Metodología

Este estudio se llevó a cabo a partir de una exhaustiva revisión bibliográfica de la literatura acerca de las cerámicas CAD-CAM disponibles para restauraciones protésicas.

Durante el procesamiento de los datos, que principalmente ha sido tramite Medline, PubMed y la Biblioteca CRAI digital de la Universidad Europea de Madrid, ha sido empleada una única ecuación de búsqueda, relacionando los términos utilizados a través de operadores booleanos: **DENTAL CERAMICS AND ((CAD-CAM) OR (prosthetic dentistry) OR (prosthodontics) OR (prosthetic restoration) OR (digital rehabilitation))**.

Durante la selección de las referencias bibliográficas, desde luego se prestó atención a las fechas de publicación, de todos modos se decidió que no hubiera limites de antigüedad. De hecho la bibliografía se divide de la siguiente forma: 10 páginas web, 14 artículos mas antiguos de los últimos 5 años (7 de estos de 2015) y 36 artículos con fecha de publicación entre 2016-2020.

Han sido criterios de inclusión: pertenecer a revistas de alto impacto, presentar resultados clínicos relevantes, incluir información acerca de cerámicas dentales CAD-CAM.

Han sido criterios de exclusión: aportar únicamente datos sobre materiales de resina y/o composites, evitar la odontología digital y el CAD-CAM.

Sucesivamente a una exhaustiva investigación, las cerámicas incluidas en esta búsqueda bibliográfica han sido seleccionadas de la siguiente forma: se han comprobado los materiales en la página oficial de su propia casa comercial y sólo se han reportado los que cumplían las características del trabajo.

Discusión

En este trabajo se ha decidido dividir las porcelanas en dos grupos. Ambos utilizan tecnología CAD-CAM, pero los tiempos para finalizar la restauración son diferentes.

Han sido clasificados según su preparación: uno comprende todas las cerámicas monolíticas (Tabla 2), tanto *chairside* como no, el otro incluye todas la porcelana utilizadas para formar la estructura del núcleo interno mecanizado y la capa de recubrimiento.

Para analizar algunos de los principales materiales disponibles se han consultado las páginas oficiales de las 9 casas comerciales reportadas en la Tabla 1. (18-26) Puesto que cada día un número mas alto de prostodoncistas y protésicos utiliza un *workflow* digital, los fabricantes se han adaptado dedicando apartados específicos en sus sitios web a la exposición de los productos CAD-CAM. A causa del hecho que la información exhibida es voluble, escasa y con tendencias a hacer parecer su producto como el mejor, ha sido indispensable objetivar este trabajo recurriendo a la literatura.

Puesto que ésta revisión bibliográfica está centrada en los materiales cerámicos, no se habla en ningún momento de composites ni de resinas (puesto que ha sido criterio de exclusión), no obstante estén presentes en el mercado para su fabricación CAD-CAM. Los únicos materiales englobados que incluyan partes de resina son las cerámicas híbridas, también conocidas como nanocerámicas.

Es cierto que los métodos sustractivos utilizados en la práctica clínica y de laboratorio para producción de restauraciones protésicas han sido considerablemente estudiados. Estos presentan una variedad generosamente amplia de materiales disponibles. De todos modos exhiben las siguientes desventajas: desperdicio cuantioso de material, diámetro limitado de las fresas, fabricación mas lenta (por ej. respecto a la estereolitografía), necesidad de acabado manual por culpa de las rugosidades dejadas por el fresado. (27)

Modernamente también se habla mucho de la metodología de fabricación por adicción. Este método ha sido introducido directamente en la clínica dental para varias aplicaciones como por ejemplo confeccionar restauraciones implantosoportadas. (27, 28) Todavía la elección de materiales es muy restringida. Los mas utilizados son los polímeros que sólo se emplean para provisionales o para modelos de trabajo. Aún no se utilizan cerámicas dentales para restauraciones protésicas a través de esta tecnología. (16) Sin embargo la circonia está disponible para procesado sustractivo y aditivo. (29) De todos modos, los objetos desarrollados por técnica aditiva en campo dental están bajo investigación para poder mejorar la calidad del acabado de superficies, las propiedades mecánicas y la precisión dimensional final. (16, 29)

Es notorio y está demostrado que los recursos sustractivos y aditivos mejoran la comunicación entre el odontólogo, el técnico y el paciente, asimismo pueden llevar a aumentar la eficiencia y la previsibilidad de tratamientos cerámicos monolíticos. (27)

Como se ha dicho anteriormente ha sido necesario reunir el conocimiento de 7 referencias (2, 12-17) para llegar a definir, y así analizar, algunas de las principales casas comerciales productoras de porcelanas odontológicas. Esto porque ninguno de los artículos incluidos en la bibliografía trata la totalidad de materiales incorporados en este trabajo. Por ejemplo en el estudio de Sulaiman (17) se analizan varios tipos de cerámicas disponibles, hablando de la composición y de las propiedades de los distintos materiales. No obstante describa algunos de los mas conocidos no hace ninguna referencia a las porcelanas fabricadas por Nobel Biocare.

Pyo et al. (28) limitan su revisión acerca de dos porcelanas (circonia y dislicato de litio), dejando atrás todas las demás opciones disponibles en el mercado digital. Es verdad que las cerámicas expuestas son entre las mas populares, pero un odontólogo no tiene que limitar sus alternativas restauradoras a unos pocos elementos, si no que debe de buscar el material mas apto en cada situación clínica. La revisión llevada a cabo por Spitznagel et al. (30) en 2018 expone muy al detalle las varias opciones restauradoras disponibles para fabricación CAD-CAM. No obstante se haga referencia a las principales porcelanas y a varios nombres comerciales conocidos, no se llegan a mencionar en ningún momento las vitrocerámicas reforzadas con circonia (ej. Initial Zr-FS, GC Europe). De todas formas es cierto que, entre estas 9 casas comerciales, la única en fabricar y distribuir este tipo de porcelana es GC Europe (Leuven, Bélgica).

Otros autores que tampoco consideran apropiado mencionar este tipo de material son Sulaiman (17) y Pyo et al. (28). Pues entonces se puede deducir que este "sub-grupo" de feldespáticas no es tan utilizado en la actualidad.

Puesto que en la mayoría de la literatura científica las porcelanas mas frecuentemente examinadas son el disilicato de litio y la circonia, es cierto que también son las mas comúnmente utilizadas en la práctica clínica.

Otros materiales muy empleados por sus propiedades elásticas y facilidad de reparación son las cerámicas híbridas, sobre todo colocadas como revestimiento en restauraciones estratificadas.

Tipos de cerámicas y restauraciones protésicas: características principales

• Cerámicas de matriz vítrea

1. Feldespática

Es una cerámica no metálica inorgánica que contiene mucha fase vítrea (feldespato, cuarzo y caolín) lo que le confiere translucidez (estética). También está compuesta por una parte cristalina, pero en un porcentaje mas bajo por lo que presenta una limitada resistencia ($\sigma 0$: 118,65 MPa verificada por VITABLOCS Mark II). (27, 31) Puesto que en su composición comprende óxido de silice (cuarzo) la fuerza de adhesión al sustrato es mayor. Entre las principales porcelanas CAD-CAM de feldespato puro en el mercado actual encontramos: CEREC Blocs C, CEREC Blocs C PC y CEREC Blocs C In de Dentsply Sirona; VITABLOCS Mark II, VITABLOCS TriLuxe forte y VITABLOCS RealLife de VITA Zahnfabrik. Estos materiales presentan composiciones casi iguales con distintos patrones de cristalización. Por ejemplo VITABLOCS Mark II (VITA Zahnfabrik) exhibe dos combinaciones ($Al_8K_2Na_6O_34Si_9$ y $AlK_{0,29}Na_{0,71}O_3Si_3$), agregando los mismos compuestos químicos. (30, 32)

Debido a sus características se utilizan fundamentalmente como revestimiento de un núcleo interno mecanizado de alta resistencia (principalmente de disilicato de litio o de circonia), pero también como coronas monolíticas y carillas. (18) Ambas partes de la restauración se pueden fabricar a través de fresadoras y sucesivamente, para fortalecer la unión entre ellas, es posible utilizar un cemento de resina. (27)

La literatura confirma su alta tasa de supervivencia a largo plazo en restauraciones tales como: *inlays*, *onlays* y coronas unitarias. (30, 33, 43) Estudios recientes, como el conducido por Lu et al. (34), reportan ajustes marginales óptimos logrados por prótesis *chairside* de porcelana feldespática.

2. Feldespática reforzada con leucita

De cerámicas con esta composición en el mercado hay dos: Initial LRF Block (GC Europe), IPS Empress CAD (Ivoclar Vivadent). No obstante sea una porcelana de matriz vítrea reforzada, con el fin de aumentar su firmeza, presenta una resistencia a la flexión biaxial de 185 MPa (según el fabricante), poco diferente de la demostrada por la literatura (187,7 MPa). (20, 30, 31)

3. Feldespática reforzada con circonia

Entre las 9 casas comerciales introducidas sólo una proporciona este tipo de material. GC Europe produce Initial Zr-FS indicada en todo tipo de restauración, pero únicamente finalizada para recubrimiento de estructuras (especialmente de óxido de circonio). (19)

Debido a la escasa documentación acerca de este material no ha sido posible aportar información adicional.

4. Silicato de litio reforzado con óxido de circonio

Disponibles hoy en día encontramos dos porcelanas de este tipo. Introducidas en 2013 para conferir una fortaleza mas elevada respecto a las antecedentes feldespáticas: Celtra Duo (Dentsply Sirona) y VITA SUPRINITY PC (VITA Zahnfabrik). (31) Se pueden utilizar para carillas, *inlays*, *onlays*, coronas unitarias. (7, 18, 25)

Según el fabricante estas porcelanas contienen un 10% en peso de partículas de circonio dispersas y presentan una resistencia a la flexión de 360 MPa. (18, 25, 30) Un reciente estudio demostró una resistencia característica σ0 de 565,87 MPa para Celtra Duo y de 537,03 MPa para VITA SUPRINITY PC. (31)

5. Disilicato de litio

El disilicato de litio es uno de los sistemas de cerámica sin metal más populares del mundo, pero entre todas las casas comerciales incorporadas en este trabajo, sólo una lo comercializa. IPS e.max CAD (Ivoclar Vivadent) contiene cristales de metasilicato de litio (Li_2SiO_3) al 40% y núcleos cristalinos ($Li_2Si_2O_5$), así estructurado para su optimización en restauraciones implantosoportadas individuales. (27, 35) Sus indicaciones sobre diente e implante unitario van desde anteriores hasta posteriores (limitándose a premolares conforme el fabricante): carillas, *inlays*, *onlays*, coronas y prótesis fijas de 3 elementos (con máximo de 1 póntico). (20, 30, 36, 37) Algunos estudios han demostrado que no hay ninguna asociación entre complicaciones y tipo de diente restaurado (premolar *vs*. molar). (37)

Está comprobado que es una de las principales cerámicas de revestimiento, también se puede utilizar como núcleo interno mecanizado, sin embargo gracias a sus características ha llegado a ser el material monolítico de elección para fabricación *chairside*. (27, 30, 31, 37)

Su resistencia a la flexión biaxial según el fabricante es de 530 MPa. (20) Mientras que un reciente estudio ha demostrado una resistencia característica σ0 de 609,8 MPa. (30, 31) En su contra Aziz et al. (37) afirman que, después de su completa cristalización, la resistencia a la flexión se queda en 360 MPa. Además presenta una tenacidad a la fractura que va de 1,4 a 2,8 MPa·√m, un módulo de elasticidad de 95 GPa, una dureza de 5,8 GPa y un coeficiente de expansión térmica de 10,5 10^{-6}/K. (27, 38-40)

• Cerámica policristalina

1. Óxido de circonio

Es una cerámica introducida desde principios de los ’90 que carece de fase vítrea. Sobre todo está compuesta por fase cristalina lo que le imparte mucha mas resistencia, pero menor estética (translucidez). (41) Además se diferencia por tener una homogeneidad monocristalina densa, una baja conductividad térmica y un bajo potencial de corrosión. (30) Por esto su rango de indicaciones es muy amplio (sobre dientes o implantes), siendo desaconsejado en sector anterior y fundamentalmente utilizado como estructura interna en sector posterior. (18, 20-26, 41)

Algunas de las principales cerámicas CAD-CAM de óxido de circonio son: CEREC Zirconia (Dentsply Sirona), Initial Zirconia Disk (GC Europe), IPS e.max ZirCAD (Ivoclar Vivadent), M-ZR multilayer HT (MERZ Dental GmbH), Katana Zirconia Block (Kuraray Noritake), NobelProcera Zirconia (Nobel Biocare), SHOFU Disk ZR Lucent (SHOFU Dental GmbH), VITA YZ (VITA Zahnfabrik), Lava Zirconia Blocks (3M ESPE).

Por supuesto muchas de ellas están disponibles para restauraciones monolíticas, así como para producción *chairside*, pudiendo reemplazar un número muy elevado de dientes (con un máximo de 2 pónticos). (27)

Este material ha registrado un resistencia a la flexión comprendida entre 900-1200 MPa, una tenacidad a la fractura de 9-10 MPa·√m y, en un reciente estudio, enseñó resultados todavía mas altos ($\sigma 0$: 1303,21 MPa). (30, 31)

La cerámica policristalina 3Y-TZP presenta las siguientes características: resistencia a la flexión biaxial (1010 MPa), tenacidad a la fractura (6,0 MPa·√m), módulo de elasticidad (220 GPa), dureza (13,2 GPa) y coeficiente de expansión térmica (10,5 10^{-6}/K, igual al de disilicato de litio). (27)

- **Cerámica de matriz de resina**

1. Nanocerámica / Cerámica híbrida

Este tipo de cerámica fue ideada con el fin de solucionar determinados problemas: disminuir la fragilidad y aumentar la elasticidad del material, así como aliviar las repercusiones sobre el antagonista (desgaste y abrasión) y la pobre durabilidad del color de los composites. (2, 4, 42)

Algunas de las principales porcelanas híbridas son: CERASMART (GC Europe), Katana Avencia Block (Kuraray Noritake), SHOFU Block HC (SHOFU Dental GmbH), VITA ENAMIC (VITA Zahnfabrik), Lava Ultimate (3M ESPE). Varias presentan una red cerámica homogénea y uniformemente distribuida. (30)

Es cierto que las cerámicas de matriz de resina se clasifican de la siguiente forma: *(1)* Compuestos a base de resina polimerizada de alta temperatura (*Resin-Based Composites*, RBCs) con rellenos dispersos y una fase predominantemente orgánica (ej. Lava Ultimate); *(2)* Materiales de red cerámica infiltrada con polímero (*Polymer-Infiltred Ceramic Network,* PICN) de alta temperatura / alta presión con una fase predominantemente inorgánica (ej. (VITA ENAMIC). (30, 43) Están indicadas para carillas, *inlays*, *onlays* y coronas unitarias. (19, 22, 24-26, 44)

Una nanocerámica muy conocida es Lava Ultimate, ésta contiene circonia-resina, mas en el detalle se compone de sílice dispersa y óxido de circonio en forma congregada y no congregada (80% en peso, 65% en volumen) impregnadas en una resina de dimetacrilato. (7, 27, 30) Presenta una resistencia a la flexión de 200 MPa y un módulo de Young de 12 GPa (similar a la dentina). (30)

Otro notorio material es VITA ENAMIC compuesto por: dimetacrilato de uretano (UDMA), polímeros reticulados de dimetacrilato de trietilenglicol (TEGDMA) y una sutil red de cerámica feldespática (86% en peso, 75% en volumen). (30, 44) Su módulo de Young está alrededor de 30 GPa y su resistencia a la flexión según el fabricante es de 160 MPa. (25, 30, 44) Un reciente estudio demostró un valor de resistencia característica σ0 de 193,45 MPa, relativamente mas elevado. (31)

Ventajas - Desventajas

Como en todo, también en la odontología digital hay “pros” y “contras”, y no obstante se lleve empleando desde hace 50 años, todavía necesita de investigaciones y mejorías para proporcionar una mayor previsibilidad. (1, 3)

Es verdad que las indicaciones de las cerámicas CAD-CAM cada vez abarcan un número mas amplio de posibilidades, pero problemas como insuficiente espacio protético o bruxismo, aún imponen algunos límites. Además ha sido demostrado que en las restauraciones protésicas se pueden manifestar con mas frecuencia problemas biológicos respecto a complicaciones técnicas. (37) Otro asunto relacionado con estas porcelanas es si influye el tipo de escáner utilizado para obtener la impresión digital. En un estudio analizaron los espacios marginales de 24 coronas de IPS e.max CAD obtenidas a través de dos escáneres: E4D (E4D Technologies LLC, Richardson, Tejas, EE.UU.) y Trios 3 (3Shape A/S, Copenhague K, Dinamarca). (45)

Finalmente vieron que no hubo diferencia significativa entre los dos aparatos. De todos modos hay que tener en cuenta las limitaciones de este estudio: las preparaciones fueron llevadas a cabo por estudiantes de pregrado sobre modelos dentales de plástico y los escaneados completados por dos operadores diferentes sin experiencia previa. En otro estudio, con el mismo propósito y condiciones, pero diferente hipótesis, se observó que los márgenes más precisos se obtuvieron cuando se utilizó un espacio de cemento de 200 μm. (46)

Dependiendo de la extensión del escaneado la impresión final será mas o menos precisa, cuanto mas largo peor, comprometiendo a la vez la restauración.

Con ella habrá que tener en cuenta muchos mas factores, responsables de la calidad del procesamiento, empezando por la experiencia del clínico y del operador que diseñará la restauración (prostodoncista o técnico). Otro elemento a tener en consideración será la maquina que la fabricará: ¿fresadora o impresora 3D?, ¿*Chairside*, de laboratorio o de centro de producción?, ¿Monolítica o estratificada?

1. **Restauraciones monolíticas** (mirar Tabla 2)

Feldespática (ej. CEREC Blocs C), feldespática reforzada con leucita (ej. Initial LRF Block), silicato de litio reforzado con circonia (ej. Celtra Duo), disilicato de litio (ej. IPS e.max CAD), circonia (ej. IPS e.max ZirCAD, M-ZR multilayer HT, Katana Zirconia Block, NobelProcera Zirconia, SHOFU Disk ZR Lucent, VITA YZ XT, Lava Zirconia Blocks), nanocerámica (ej. CERASMART, Katana Avencia Block, SHOFU Block HC, VITA ENAMIC).

Tabla 2: las principales cerámicas monolíticas en comercio.

CASA COMERCIAL	(1) Matriz vítrea	(2) Policristalinas	(3) Matriz de resina
Dentsply Sirona, York, Pensilvania, EE.UU. (18)	- CEREC Blocs C* - CEREC Blocs C PC* - CEREC Blocs C In* - Celtra Duo*	- Cercon HT - inCoris ZI* - inCoris TZI* - inCoris TZI C* - CEREC Zirconia* - CEREC Zirconia meso*	NP
GC Europe, Leuven, Bélgica (19)	Initial LRF Block*	NP	- CERASMART* - CERASMART 270*
Ivoclar Vivadent, Schaan, Liechtenstein (20)	- IPS Empress CAD* - IPS e.max CAD*	- IPS e.max ZirCAD* - IPS e.max ZirCAD Prime*	NP

Tabla 2: las principales cerámicas monolíticas en comercio.			
CASA COMERCIAL	**(1) Matriz vítrea**	**(2) Policristalinas**	**(3) Matriz de resina**
Merz dental GmbH, Lütjenburg, Alemania (21)	NP	- M-ZR multilayer HT - M-ZR multilayer HT+ - M-ZR multicolor ST - M-ZR color HT - M-ZR white HT	NP
Kuraray Noritake, Kurashiki, Japón (22)	NP	- Katana Zirconia Block* - Katana Zirconia	Katana Avencia Block*
Nobel Biocare, Zurigo, Suiza (23)	NP	- NobelProcera Zirconia - Nacera Pearl Shaded	NP
SHOFU Dental GmbH, Ratingen, Alemania (24)	NP	SHOFU Disk ZR Lucent	- SHOFU Block HC* - SHOFU Disk HC
VITA Zahnfabrik, Bad Säckingen, Alemania (25)	- VITABLOCS Mark II* - VITABLOCS TriLuxe forte* - VITABLOCS RealLife*	VITA YZ*	VITA ENAMIC*
3M ESPE, St. Paul, Minesota, EE.UU. (26)	NP	- Lava Zirconia Blocks* - 3M Lava Esthetic Fluorescent Full-	Lava Ultimate*

Tabla 2: las principales cerámicas monolíticas en comercio.			
CASA COMERCIAL	**(1) Matriz vítrea**	**(2) Policristalinas**	**(3) Matriz de resina**
		Contour Zirconia Disc - 3M Chairside Zirconia*	
Abreviatura: NP (no produce) * Disponible para *chairside*			

Los sistemas de planificación y fabricación digitales cada vez son mejores, mas rápidos, mas predecibles y al alcance de un número mayor de técnicos y clínicos. Está demostrado el significativo ahorro de tiempo que garantizan, en particular las restauraciones a contorno completo. De hecho, comparado con un método de producción tradicional, se pueden ahorrar aproximadamente unas 2-3 horas, fabricando a la vez múltiples prótesis para diferentes pacientes. (47) Puesto que ya se puede restaurar prácticamente cualquier sextante, siendo los sectores posteriores los mas indicados, el empleo de restauraciones monolíticas ha aumentado notablemente. (18-26, 35) Debido a su peor estética respecto a las multicapa no es común utilizarlas en sectores anteriores. No obstante esto hay cerámicas, de matriz vítrea o de resina, pero no policristalinas, con las que se pueden producir carillas directamente "*in-office*" (ej. CEREC Blocs C, CERASMART). (18, 19) Además, es cierto que las feldespáticas han demostrado ser las porcelanas con mayor durabilidad a la tinción. (48) Hasta se ha comprobado la eficacia de las restauraciones a contorno completo en pilares de prótesis parciales removibles. (49)

En un estudio conducido por Seydler y Schmitter (50) se relacionaron 30 coronas de disilicato de litio monolíticas fabricadas por flujo digital con otras 30 estratificadas (estructura de circonia recubierta de disilicato de litio también elaborado por CAD-CAM). Las restauraciones monolíticas demostraron producir menos problemas de *chipping*. En la evaluación a dos años de seguimiento, en ambos grupos se notó la ausencia de complicaciones como fracturas, desprendimientos del material (*chipping*) o grietas, únicamente hubo algunos problemas biológicos. Es cierto que el número de sujetos estudiados junto al total de restauraciones evaluadas es bajo. Además todas las mediciones que llevaron a cabo, por supuesto muy detalladamente, se limitaron a tres citas (a los 14 días, al año y a los 2 años). Posteriormente a éstas consideraciones es complicado confirmar la hipótesis inicial del estudio, o sea que el número de complicaciones sería menor para las restauraciones monolíticas. De todas formas la menor magnitud de *chipping* por parte de las monolíticas está demostrada. (28, 30, 35, 37, 41, 50)

En otro estudio, Akın et al. (44) enfrentaron dos grupos de 15 coronas de disilicato de litio: unas fabricadas por tecnología CAD-CAM y las otras por método convencional. Quisieron comparar la adaptación y el ajuste marginal e interno de estas restauraciones. No hubo diferencias relevantes entre las dos técnicas de fabricación. La media de espacio marginal determinada fue la siguiente: 132,2 μm (grupo CAD-CAM) y 130,2 μm (grupo convencional). Las limitaciones de este estudio, como por ejemplo las bajas muestras y un seguimiento de apenas dos años, no son suficientes para llegar a unas conclusiones satisfactorias.

De la misma manera se pueden producir prótesis a contorno completo a través de nanocerámicas, las cuales también han demostrado ser menos susceptibles a fracturas y desprendimiento de material. (38) Además, es cierto que las cerámicas híbridas se fresen, pulan y reparen con mayor facilidad respecto a las demás porcelanas. Sin embargo, todavía presentan propiedades mecánicas reducidas y mala resistencia al desgaste. (51)

Resumiendo, las principales ventajas que aportan las restauraciones CAD-CAM monolíticas son: producción mas rápida, disponible para *chairside,* menor presencia de *chipping,* grietas y/o fracturas respecto a las multicapa, ausencia de delaminación (“*delamination*” o “*debondign*”), mejor ajuste interno y marginal, alta resistencia por parte de las policristalinas, preparación dental mas conservativa. (18-26, 28, 30, 35, 37, 41, 45, 48, 50)

Mientras que las desventajas fundamentales son las siguientes: menor estética y ausencia de efecto camaleónico en un entorno de dientes naturales por parte de las restauraciones sin maquillar, necesidad de maquillaje, limitación en la elección de materiales, desperdicio de material con dificultad para recuperar los restos durante el fresado y fuerte desgaste de las herramientas de fresado, propiedades mecánicas reducidas y mala resistencia al desgaste de las cerámicas híbridas, imposibilidad de retocar las restauraciones finales de circonia, menor precisión por parte de las fresadoras *chairside* (cuantos mas ejes mas detalles) respecto a las de un centro de producción, estereolitografía (SLA) todavía limitada (detalles, materiales, precios), elevado coste de inversión, necesidad de mas investigaciones. (16, 19, 20, 27, 29, 41, 47)

2. Restauraciones estratificadas o multicapa (*multilayered*)

- Estructura: cerámicas policristalinas (ej. inCoris ZI), de matriz de resina (ej. VITA ENAMIC) y todas las monolíticas excluyendo las feldespáticas.
- Cargada: cerámicas de matriz vítrea (ej. VITABLOCS TriLuxe forte) y nanocerámicas (ej. VITA ENAMIC multiColor)

La literatura habla esencialmente de tres técnicas de recubrimiento digital: CAD-on (Ivoclar Vivadent), Lava DVS (*Digital Veneering System*, 3M ESPE) y *Rapid Layer Technology* (VITA Zahnfabrik). (53, 54) La mayoría de los estudios in vitro apoyan la conclusión por la cual el CAD-on sea el mejor método, puesto que aumenta la resistencia a la fractura y la fuerza de unión entre estructura de circonia y cerámica de recubrimiento, en restauraciones de coronas. (54-58)

Es cierto que el *chipping* sea una de las principales complicaciones relacionadas con éste tipo de prótesis. (27, 28, 30, 36, 41, 52-54, 56, 59) De todos modos también es verdad que las restauraciones estratificadas fabricadas por *workflow* digital padecen una resistencia mayor a eventuales problemas y menores fallos de adhesividad entre estructura y cerámica de recubrimiento ("*delamination*" o "*debonding*"), comparadas con las fabricadas por técnica convencional. (52, 53, 57) En un estudio clínico con seguimiento a cinco años, llevado a cabo por Vigolo y Mutinelli (59), analizaron 60 restauraciones unitarias fijas sobre molares inferiores (derechos e izquierdos). Éstas fueron divididas en tres grupos: 20 de metal porcelana y 40 de porcelana estratificada sin metal (20 de Nobel Biocare y 20 de 3M ESPE) producidas por dos sistemas CAD-CAM diferentes. Al final del estudio no hubo diferencias estadísticamente significativas entre metal porcelana y cerámicas CAD-CAM. De todos modos los datos clínicos demostraron que los grupos de porcelana de óxido de circonio tendían a tener frecuentemente más problemas (ej. fracturas extendidas del recubrimiento cerámico). Es cierto que el *gold standard* de las restauraciones protésicas son las de metal cerámica, debido a sus excelentes prestaciones clínicas científicamente comprobadas. (41, 51) No obstante ésto, cada año se utilizan menos debido a su menor biocompatibilidad, menor translucidez y el incremento de demanda para restauraciones altamente estéticas. Así es como la cerámica está arrebatando el sitio del metal como material de elección para los núcleos internos mecanizados en restauraciones multicapa. (41, 51)

En un reciente estudio conducido por Benic et al. (60), en el que pusieron en debate prótesis completamente cerámicas contra otras de metal porcelana, se demostró un ajuste similar o mejor por parte de las restauraciones CAD-CAM de circonia en la región del hombro. Mientras que fueron alcanzados resultados mas favorables por parte de las de metal cerámica en la región oclusal.

Gracias a los avances tecnológicos es posible fabricar tanto la estructura como el recubrimiento a través de *workflow* digital y sucesivamente unir las dos partes por un cemento de resina o con una cerámica de vidrio fundida. (27, 41, 51, 57)

Resumiendo, las principales ventajas que aportan las restauraciones CAD-CAM multicapa son: mejor estética, envejecimiento mas lento y mayor durabilidad a la tinción de las feldespáticas, procesamiento CAD-CAM disponible para estructura y cerámica externa, menor presencia de delaminación, *chipping*, grietas y fracturas respecto a las producidas por método tradicional, mayor disponibilidad de materiales, presencia de mas estudios clínicos respecto a las monolíticas. (27, 41, 48, 51, 57)

Mientras que las desventajas fundamentales son las siguientes: presencia de delaminación (se define como el fallo adhesivo entre estructura y cerámica de recubrimiento), mayor *chipping*, grietas y fracturas respecto a las monolíticas, mayor tiempo de fabricación, baja resistencia por parte de las feldespáticas, necesidad de mayor remoción de estructura dental por oclusal durante la preparación. Además, influyen mucho en la resistencia de estas restauraciones los siguientes factores: diseño del núcleo interno mecanizado, relación entre los espesores de las capas de recubrimiento, propiedades mecánicas de la cerámica externa, tensiones térmicas residuales dentro de la restauración. (27, 28, 30, 36, 41, 42, 47, 52-54, 56, 57, 59)

Cerámicas CAD-CAM de las distintas casas comerciales: indicaciones y ventajas

A continuación se presentan algunas de las principales cerámicas disponibles actualmente en el mercado para confeccionar restauraciones dentales a través de flujo digital CAD-CAM. Todos los materiales marcados con un "*" son disponibles para uso *chairside*.

Al fondo se resume en una tabla (Tabla 3) todas las indicaciones de éstas porcelanas.

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1. **DENTSPLY SIRONA,** York, Pensilvania, EE.UU. (18)

- **Cerámicas de matriz vítrea: feldespática**

1. CEREC Blocs C*

Indicaciones: carillas, *inlay*, *onlay*, corona monolítica.

Ventajas: estética, propiedades similares al esmalte, alta translucidez, buen pulido final, fluorescencia blanca, efecto camaleónico, biocompatibilidad.

2. CEREC Blocs C PC*

Indicaciones: carillas, *inlay*, *onlay*, corona anterior, optimizado para corona posterior.

Ventajas: estética, buena personalización debido a sus tres capas, biocompatibilidad.

3. CEREC Blocs C In*

Indicaciones: corona anterior.

Ventajas: estética, núcleo de dentina y capa translúcida de esmalte, algoritmo CEREC / inLab, biocompatibilidad.

- **Cerámicas de matriz vítrea: silicato de litio reforzado con circonia**

1. Celtra Duo*

Indicaciones: carillas, *inlay*, *onlay*, corona unitaria, se puede utilizar para restauraciones monolíticas (ej. corona monolítica).

Contraindicaciones: recubrimiento completo de corona de molares, preparaciones subgingivales muy profundas, pacientes con muy pocos dientes remanentes, bruxistas.

Ventajas: estética, alta opalescencia, fluorescencia, translucidez, resistencia, biocompatibilidad.

- **Cerámicas policristalinas: circonia**

1. Cercon

Indicaciones: tanto para sector anterior como posterior.

- Cercon XT: corona, puente de 3 unidades.
- Cercon HT: corona, puente de múltiples unidades (hasta 6 unidades con un máximo de 2 pónticos), corona telescópica, se puede utilizar como estructura y restauraciones monolíticas.

Contraindicaciones: no se debe de usar en pacientes con hipersensibilidad a la circonia, bruxistas, insuficiente espacio protético, con poste, como prótesis sobre implantes, puente de inlays, puente de 3 unidades en molares (sólo para Cercon XT).

Ventajas: estética, ahorro de tiempo, proporciona estabilidad, alta biocompatibilidad.

2. inCoris ZI meso

Indicaciones: mesoestructuras diseñadas individualmente, que se pegan a una base de titanio adecuada después del fresado y sinterizado.

Contraindicaciones: higiene bucal insuficiente, espacio protético insuficiente, en caso de bricomanía, restauraciones con angulación > 20° respecto al eje del implante, en caso de un sólo diente con elemento voladizo (*cantilever*), restauraciones cuya longitud en relación a la longitud del implante sea superior a 1:1,25.

Ventajas: alta resistencia, resistente a la corrosión, excelente biocompatibilidad.

3. inCoris ZI*

Indicaciones: cofias anteriores y posteriores, estructura de puentes (hasta 2 pónticos), corona telescópica, barra, elementos de sujeción.

Ventajas: alto rendimiento, excelente resistencia, larga vida útil, excepcional disposición de procesamiento, excelente biocompatibilidad.

4. inCoris TZI*

Indicaciones: coronas monolíticas anteriores y posteriores, puentes monolíticos anteriores y posteriores (con un máximo de 2 pónticos).

Contraindicaciones: higiene bucal insuficiente, resultados de la preparación no satisfactorios, esmalte insuficiente, espacio protético insuficiente.

Ventajas: alta translucidez, solidez, resistencia a la corrosión, biocompatibilidad.

5. inCoris TZI C*

Indicaciones: coronas y puentes monolíticos, corona telescópica, barra, elementos de sujeción.

Ventajas: menor tiempo de preparación, color exacto, evita la formación de astillas, biocompatibilidad.

6. CEREC Zirconia*

Indicaciones: coronas y puentes monolíticos (hasta 3 unidades con un máximo tramo mesiodistal clínico de 30 mm) anteriores y posteriores, casos con poco espacio protético, casos con poco espesor residuo de pared axial, casos donde la unión adhesiva no es deseada.

Ventajas: preparación mínimamente invasiva, para casos con poco espacio protético, restauraciones de contorno completo, precoloreada, biocompatibilidad.

7. CEREC Zirconia meso*

Indicaciones: corona retenida atornillada, corona parcial.

Ventajas: menor tiempo de preparación, estética, buen ajuste, alta resistencia, alta biocompatibilidad.

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2. **GC EUROPE,** Leuven, Bélgica (19)

- **Cerámicas de matriz vítrea: feldespática reforzada con leucita**

1. Initial LRF Block*

Indicaciones: carillas, *inlay*, *onlay*, corona parcial, coronas monolíticas anteriores y posteriores, endocoronas en molares.

Ventajas: estética, translucidez, fluorescencia, carácter opalescente, fácil manejo, alta densidad (menor riesgo de *chipping*), efecto camaleónico, biocompatibilidad.

- **Cerámicas de matriz vítrea: feldespática reforzada con circonia**

1. Initial Zr-FS

Indicaciones: todo tipo de restauraciones.

Ventajas: muy estética, tiempo de enfriamiento corto, buena humectabilidad, alta estabilidad, superficies lisas, biocompatibilidad.

- **Cerámicas policristalinas: circonia**

1. Initial Zirconia Disk

Indicaciones:

- Initial Zirconia Disk ST y HT: coronas anteriores y posteriores, puentes (hasta 3 unidades), pilares híbridos, estructuras sobre implantes.
- Initial Zirconia Disk UHT: carillas, *inlay*, *onlay*, coronas anteriores y posteriores, puentes (hasta 3 unidades).

Ventajas: elevada estética, elevada translucidez, elevada resistencia, excelente estabilidad, fácil fresado, personalizable con Initial Lustre Pastes NF, biocompatibilidad.

- **Cerámicas de matriz de resina: híbrida**

1. CERASMART*

Indicaciones: carillas, *inlay*, *onlay*, corona posterior, corona sobre implante.

Ventajas: resistencia a la abrasión, superficies lisas y brillantes a largo plazo, bajo desgaste con el antagonista, alta flexibilidad, amortiza fuerzas masticatorias, fresado rápido, buen ajuste marginal, personalizable con OPTIGLAZE color, fluorescencia, opalescencia, biocompatibilidad.

2. CERASMART270*

Indicaciones: carillas, *inlay*, *onlay*, corona posterior, corona sobre implante.

Ventajas: estética, fuerte adhesión, resistencia a la abrasión, superficies lisas y brillantes a largo plazo, bajo desgaste con el antagonista, alta flexibilidad, amortiza fuerzas masticatorias, fresado rápido, perfecto ajuste marginal, personalizable con OPTIGLAZE color, fluorescencia, opalescencia, biocompatibilidad.

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3. IVOCLAR VIVADENT, Schaan, Liechtenstein (20)

- **Cerámicas de matriz vítrea: feldespática reforzada con leucita**

1. IPS Empress CAD*

Indicaciones: carillas, *inlay*, *onlay*, coronas parciales, coronas anteriores.

Ventajas: alta estética, propiedades ópticas de luz brillante, alta estabilidad, fluorescencia, efecto camaleónico, no necesita caracterización adicional, ajuste excelente, biocompatibilidad.

- **Cerámicas de matriz vítrea: disilicato de litio**

1. IPS e.max CAD*

Indicaciones: carillas (≥0,4 mm), carillas oclusales, *inlay*, *onlay*, coronas parciales, coronas mínimamente invasivas (≥1 mm) anteriores y posteriores, puentes (hasta 3 unidades, hasta segundo premolar como pilar terminal).

Ventajas: muy buenas propiedades ópticas de luz, estética, confiabilidad clínica demostrada, éxito clínico a largo plazo, biocompatibilidad.

- **Cerámicas policristalinas: circonia**

1. IPS e.max ZirCAD*

Indicaciones: restauraciones de piezas con bajos espesores de paredes, coronas y puentes anteriores y posteriores monolíticos, estructuras de coronas y puentes, superestructuras implantosoportadas.

Ventajas: alta estética, alta resistencia mecánica, alta tenacidad a la fractura, biocompatibilidad.

2. IPS e.max ZirCAD Prime*

Indicaciones: coronas anteriores y posteriores, puentes anteriores y posteriores (hasta 14 piezas), coronas monolíticas, puentes monolíticos (hasta 3 piezas), puentes monolíticos (≥4 piezas con máximo 2 pónticos), estructuras de coronas y puentes (≥3 piezas con máximo 2 pónticos).

Ventajas: alta estética, alta resistencia mecánica, alta tenacidad a la fractura, biocompatibilidad.

4. **MERZ DENTAL GmbH,** Lütjenburg, Alemania (21)

- **Cerámicas policristalinas: circonia**

1. M-ZR multilayer HT

Indicaciones: coronas y puentes (hasta 3 unidades de máximo 1 póntico) anteriores y posteriores, coronas y puentes monolíticos anteriores y posteriores, coronas y puentes anteriores fabricados con *cut-back.*

Ventajas: estética natural, alta resistencia, tenacidad a la fractura, buen ajuste, densidad uniforme, biocompatibilidad.

2. M-ZR multilayer HT+

Indicaciones: carillas, *inlay*, *onlay*, corona parcial, corona anterior y posterior monolítica, corona con pilar híbrido, puente monolítico (hasta 3 elementos), puente reducido (hasta 3 elementos).

Ventajas: estética, alta resistencia, buen grado de translucidez, biocompatibilidad.

3. M-ZR multicolor ST

Indicaciones: carillas, *inlay*, *onlay*, corona parcial, corona anterior y posterior monolítica, corona con pilar híbrido, puente monolítico (hasta 3 unidades), puente monolítico (≥ 4 unidades con máximo 2 elementos adyacentes), puente reducido (≥ 4 elementos con máximo 2 elementos adyacentes).

Ventajas: estética, resistencia, no necesita de caracterización, ahorro de tiempo, biocompatibilidad.

4. M-ZR color HT

Indicaciones: corona parcial, corona anterior y posterior monolítica, corona con pilar híbrido, puente monolítico (hasta 3 elementos), puente monolítico (≥ 4 elementos con máximo 2 elementos adyacentes), puente reducido (≥ 4 elementos con máximo 2 elementos adyacentes), barra.

Ventajas: estética, resistencia, translucidez, biocompatibilidad.

5. M-ZR white HT

Indicaciones: carillas, corona parcial, corona posterior monolítica, corona con pilar híbrido, puente monolítico (≥ 4 elementos), puente reducido (≥ 4 elementos), pilar híbrido, barra.

Ventajas: estética, resistencia, translucidez, biocompatibilidad.

5. **KURARAY NORITAKE,** Kurashiki, Japón (22)

- **Cerámicas policristalinas: circonia**

1. Katana Zirconia Block*

Indicaciones: coronas y puentes (hasta 3 unidades) anteriores y posteriores monolíticos.

Ventajas: estética, alta translucidez, alta resistencia a la flexión, sinterización ultrarrápida, ahorro de tiempo, biocompatibilidad.

2. Katana Zirconia

Indicaciones: carillas, *inlay*, *onlay*, corona y puente anterior y posterior (> de 4 elementos), corona y puente anterior y posterior monolíticos (> de 4 elementos).

Ventajas: estética, 4 niveles de translucidez, se puede combinar con Cerabien ZR FC Paste Stain o CerabienTM ZR, alta resistencia, translucidez, biocompatibilidad.

- **Cerámicas de matriz de resina: híbrida**

1. Katana Avencia Block*

Indicaciones: *inlay*, *onlay*, corona anterior y posterior.

Ventajas: estética, rápida, natural, resistente, biocompatibilidad.

6. **NOBEL BIOCARE,** Zurigo, Suiza (23)

- **Cerámicas policristalinas: circonia**

1. NobelProcera Zirconia

Indicaciones: coronas y puentes (hasta 5 unidades), cofias, estructuras de puente (hasta 14 unidades), coronas y pilares atornilladas monolíticos, puente implantosoportado monolítico (2-5 unidades).

Ventajas: estética, alta translucidez, ahorra tiempo, bajo riesgo de *chipping*, biocompatibilidad.

2. Nacera Pearl Shaded

Indicaciones: puentes implantosoportados monolíticos (2-14 unidades) anterior y posterior, estructuras de puente anteriores y posteriores, disponible con/sin encía.

Ventajas: estética, resistencia, biocompatibilidad.

3. NobelPearl

Indicaciones: material utilizado para producir implantes y pilares.

Ventajas: 100% libre de metal, conexión interna sin cemento, compatible con el tejido blando y biotipo fino, alternativa al titanio, poca afinidad con la placa, biocompatibilidad.

4. DOCERAM Nacera Pearl Zirconia

Descripción: nuevo material. No se ha encontrado información.

7. **SHOFU DENTAL GmbH,** Ratingen, Alemania, (24)

- **Cerámicas policristalinas: circonia**

1. SHOFU Disk ZR Lucent

Indicaciones: carillas, *inlay*, *onlay*, coronas y puentes monolíticos anteriores (hasta 6 unidades) y posteriores (hasta 3 unidades), estructuras reducidas para coronas y puentes anteriores (hasta 6 unidades) y posteriores (hasta 3 unidades).

Ventajas: estética, translucidez natural, alta estabilidad, alta resistencia, fluorescencia natural, biocompatibilidad.

- **Cerámicas de matriz de resina: híbrida**

1. SHOFU Block HC*

Indicaciones: carillas, *inlay*, *onlay*, coronas monolíticas anteriores y posteriores, coronas monolíticas anteriores y posteriores sobre implantes.

Ventajas: alta estabilidad a largo plazo, difusión de luz realista, absorbe el estrés, fluorescencia realista, buenas propiedades de manipulación y fresado, biocompatibilidad.

2. SHOFU Disk HC

Indicaciones: carillas, *inlay*, *onlay*, coronas monolíticas anteriores y posteriores, coronas monolíticas anteriores y posteriores sobre implantes.

Ventajas: alta estabilidad a largo plazo, difusión de luz realista, absorbe el estrés, fluorescencia realista, buenas propiedades de manipulación y fresado, biocompatibilidad.

8. **VITA ZAHNFABRIK,** Bad Säckingen, Alemania (25)

- **Cerámicas de matriz vítrea: feldespática**

1. VITABLOCS Mark II*

Indicaciones: *inlay*, *onlay*, coronas parciales.

Ventajas: alta estética, rápida confección, biocompatibilidad.

2. VITABLOCS TriLuxe forte*

Indicaciones: carillas, coronas en zonas visibles.

Ventajas: alta estética, rápida confección, biocompatibilidad.

3. VITABLOCS RealLife*

Indicaciones: coronas anteriores.

Ventajas: estética, rápida confección, biocompatibilidad.

- **Cerámicas de matriz vítrea: silicato de litio reforzado con circonia**

1. VITA SUPRINITY PC

Indicaciones: carillas, coronas anteriores y posteriores, corona implantosoportada.

Ventajas: alta estética, alta resistencia, gran precisión, fácil manipulación, buena estabilidad, flurescencia, opalescencia, biocompatibilidad.

- **Cerámicas policristalinas: circonia**

1. VITA YZ*

Indicaciones: todas disponibles para coronas monolíticas *chairside*.

- VITA YZ XT: carillas, carillas oclusales (*table top*), *inlay*, *onlay*, coronas parciales, corona anterior y posterior, puentes anteriores y posteriores (hasta 3 elementos), estructura de puentes anteriores y posteriores (hasta 3 elementos).
- VITA YZ ST: carillas, carillas oclusales (*table top*), *inlay*, *onlay*, coronas parciales, puentes anteriores y posteriores (hasta 14 elementos), cofia de corona, estructura de puentes anteriores y posteriores (hasta 14 elementos), estructura de corona individual sobre restauración atornillada, estructura de puente sobre restauración atornillada (hasta 14 elementos).
- VITA YZ HT: puentes anteriores y posteriores (hasta 14 elementos), cofia de corona, estructura de puentes anteriores y posteriores (hasta 14 elementos), estructura de corona individual sobre restauración atornillada, estructura de puentes sobre restauración atornillada (hasta 14 elementos), coronas telescópicas.
- VITA YZ T: puentes anteriores y posteriores (hasta 14 elementos con un máximo de 2 pónticos contiguos), cofia de corona, estructura de puentes anteriores y posteriores (hasta 14 elementos con un máximo de 2 pónticos contiguos), estructura de corona individual sobre restauración atornillada, estructura de puentes sobre restauración atornillada (hasta 14 elementos con un máximo de 2 pónticos contiguos), coronas telescópicas.

Ventajas: estética, reproducción fiable de colores dentales, microestructura homogénea, buen ajuste, biocompatibilidad.

- **Cerámicas de matriz de resina: híbrida**

1. VITA ENAMIC*

Indicaciones: reconstrucciones con grosores de pared reducidos, coronas posteriores, *inlay*, reconstrucción no invasiva/mínimamente invasiva de superficies oclusales (*table top*), estructuras monolíticas para puentes.

- VITA ENAMIC T: coronas posteriores, posibilidad de confeccionar cofias.
- VITA ENAMIC HT: carillas, carillas oclusales, corona parcial, coronas anteriores y posteriores, posibilidad de confeccionar *inlay*, *onlay*, corona sobre implante.
- VITA ENAMIC ST: carillas, *inlay*, *onlay*, posibilidad de confeccionar carillas oclusales, corona anterior, corona parcial.

Ventajas: absorción de fuerza, tratamientos no invasivos, restauraciones delgadas, buen ajuste, biocompatibilidad.

2. VITA ENAMIC IS

Indicaciones: corona sobre pilar implantosoportada, mesoestructuras.

- VITA ENAMIC IS T: cofias, posibilidad de confeccionar corona sobre implante.
- VITA ENAMIC IS HT: corona sobre implante, posibilidad de confeccionar cofias.

Ventajas: absorción de fuerzas, alta carga, ahorro de tiempo, biocompatibilidad.

3. VITA ENAMIC multiColor

Indicaciones: carillas, coronas anteriores y posteriores.

Ventajas: estética, absorción de fuerzas, alta carga, tallado mínimamente invasivo, restauraciones delgadas, buen ajuste, ahorro de tiempo, biocompatibilidad.

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9. **3M ESPE,** St. Paul, Minesota, EE.UU. (26)

- **Cerámicas policristalinas: circonia**

1. Lava Plus HT Zirconia Disc

Indicaciones: *inlay*, *onlay*, coronas anteriores y posteriores, corona sobre implante, coronas ferulizadas (hasta 4 unidades), puentes anteriores y posteriores, puente voladizo (*cantilever*), puente *maryland*, estructuras de pilares, puente sobre implantes (hasta 3 unidades), puente de arco completo.

Ventajas: no desgasta el antagonista, alta estabilidad, alta resistencia, buen ajuste, fácil manejo, biocompatibilidad.

2. Lava Zirconia Blocks*

Indicaciones: *inlay*, *onlay*, coronas anteriores y posteriores, corona monolítica, coronas ferulizadas, puentes anteriores y posteriores (hasta 6 unidades), puente voladizo (*cantilever*), corona telescópica, pilar híbrido.

Ventajas: alta estética, alta estabilidad, alta resistencia, buen ajuste, biocompatibilidad.

3. 3M Lava Esthetic Fluorescent Full-Contour Zirconia Disc

Indicaciones: carillas, *inlay*, *onlay*, coronas anteriores y posteriores, corona monolítica, puentes anteriores y posteriores (hasta 3 unidades con máximo 1 póntico).

Ventajas: alta estética, alta resistencia, alta estabilidad, buen ajuste, fluorescencia, alta translucidez, biocompatibilidad.

4. 3M Chairside Zirconia*

Indicaciones: coronas anteriores y posteriores, puente (hasta 3 unidades).

Ventajas: estética, alta resistencia, rápida sinterización, biocompatibilidad.

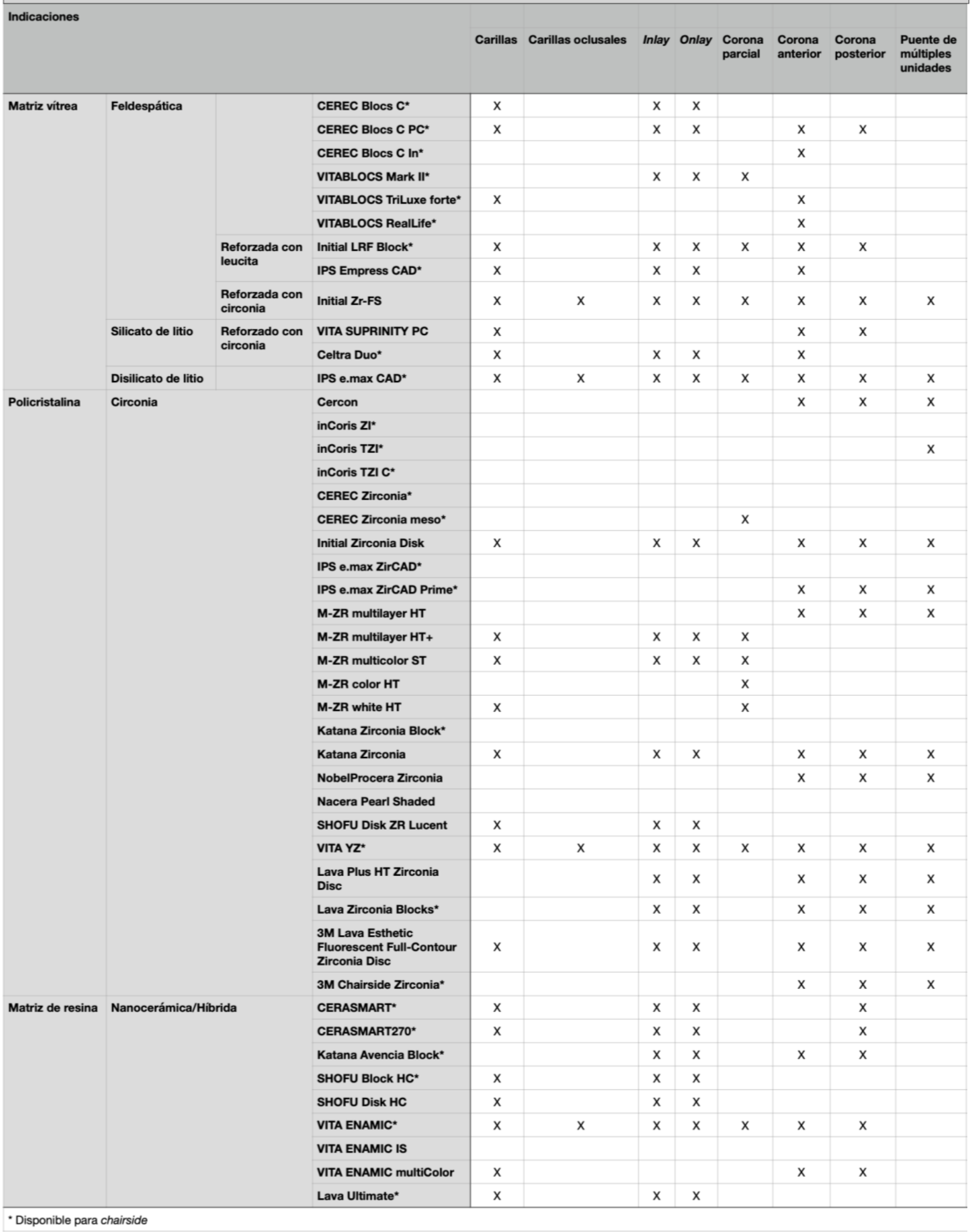
- **Cerámicas de matriz de resina: híbrida**

1. Lava Ultimate*

Indicaciones: carillas, *inlay*, *onlay*.

Ventajas: buena estética, alta estabilidad, no desgasta su antagonista, buen ajuste, biocompatibilidad.

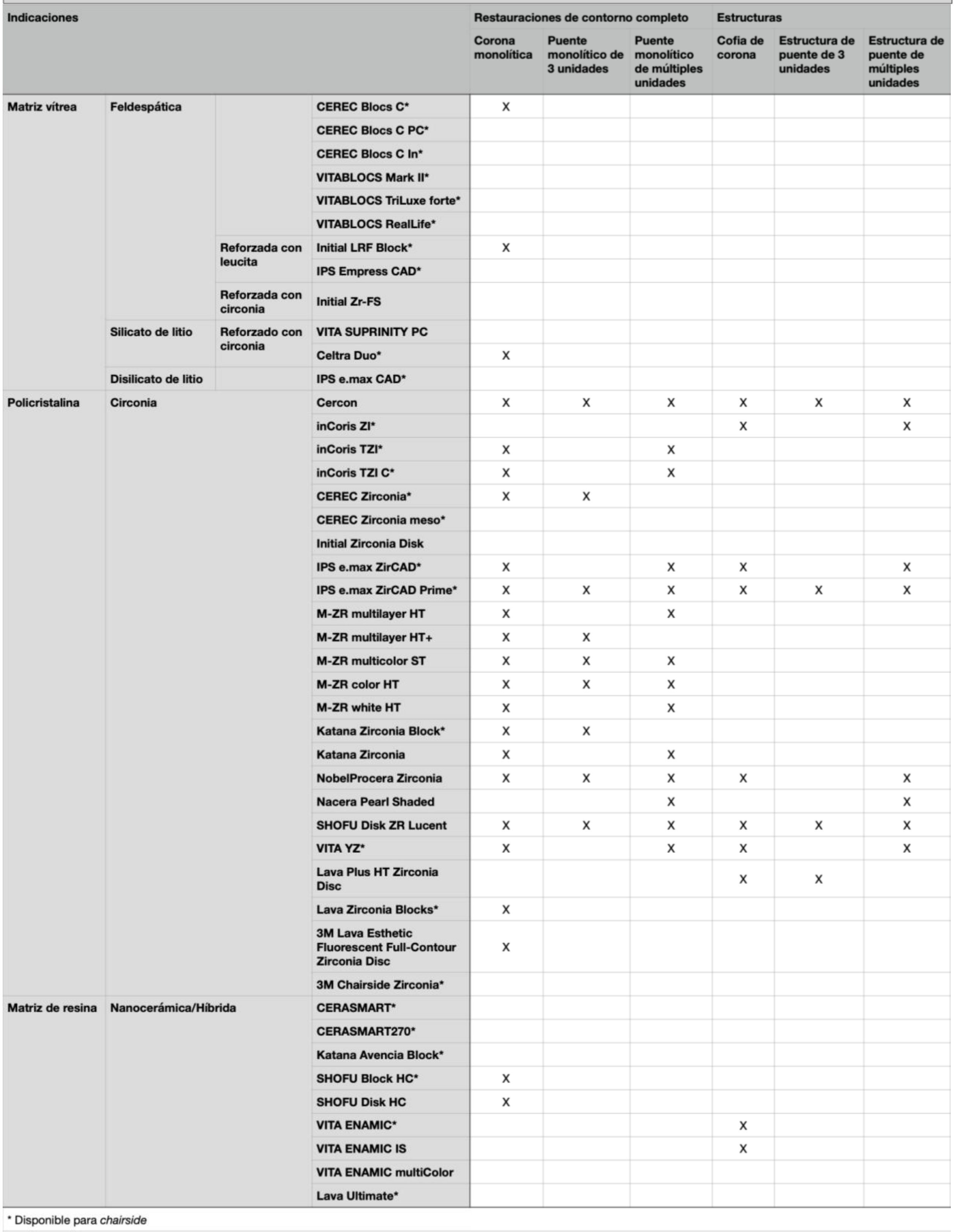
Tabla 3: indicaciones de las principales cerámicas CAD-CAM en comercio.



Indicaciones				Carillas	Carillas oclusales	*Inlay*	*Onlay*	Corona parcial	Corona anterior	Corona posterior	Puente de múltiples unidades
Matriz vítrea	Feldespática		CEREC Blocs C*	X		X	X				
			CEREC Blocs C PC*	X		X	X		X	X	
			CEREC Blocs C In*						X		
			VITABLOCS Mark II*			X	X	X			
			VITABLOCS TriLuxe forte*	X					X		
			VITABLOCS RealLife*						X		
		Reforzada con leucita	Initial LRF Block*	X		X	X	X	X	X	
			IPS Empress CAD*	X		X	X		X		
		Reforzada con circonia	Initial Zr-FS	X	X	X	X	X	X	X	X
	Silicato de litio	Reforzado con circonia	VITA SUPRINITY PC	X					X	X	
			Celtra Duo*	X		X	X		X		
	Disilicato de litio		IPS e.max CAD*	X	X	X	X	X	X	X	X
Policristalina	Circonia		Cercon						X	X	X
			inCoris ZI*								
			inCoris TZI*								X
			inCoris TZI C*								
			CEREC Zirconia*								
			CEREC Zirconia meso*					X			
			Initial Zirconia Disk	X		X	X		X	X	X
			IPS e.max ZirCAD*								
			IPS e.max ZirCAD Prime*						X	X	X
			M-ZR multilayer HT						X	X	X
			M-ZR multilayer HT+	X		X	X	X			
			M-ZR multicolor ST	X		X	X	X			
			M-ZR color HT					X			
			M-ZR white HT	X				X			
			Katana Zirconia Block*								
			Katana Zirconia	X		X	X		X	X	X
			NobelProcera Zirconia						X	X	X
			Nacera Pearl Shaded								
			SHOFU Disk ZR Lucent	X		X	X				
			VITA YZ*	X	X	X	X	X	X	X	X
			Lava Plus HT Zirconia Disc			X	X		X	X	X
			Lava Zirconia Blocks*			X	X		X	X	X
			3M Lava Esthetic Fluorescent Full-Contour Zirconia Disc	X		X	X		X	X	X
			3M Chairside Zirconia*						X	X	X
Matriz de resina	Nanocerámica/Híbrida		CERASMART*	X		X	X			X	
			CERASMART270*	X		X	X			X	
			Katana Avencia Block*			X	X		X	X	
			SHOFU Block HC*	X		X	X				
			SHOFU Disk HC	X		X	X				
			VITA ENAMIC*	X	X	X	X	X	X	X	
			VITA ENAMIC IS								
			VITA ENAMIC multiColor	X					X	X	
			Lava Ultimate*	X		X	X				

* Disponible para *chairside*

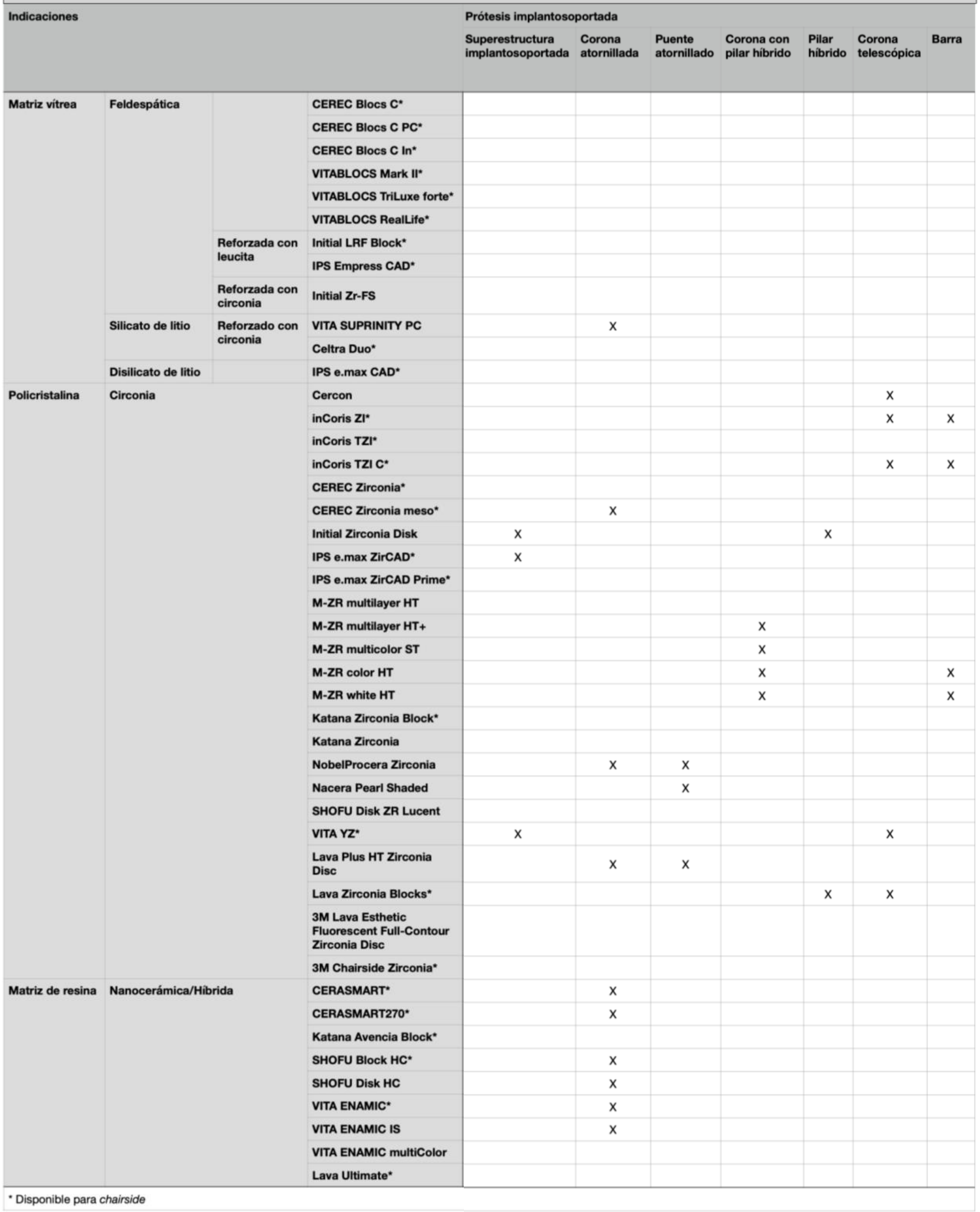
Tabla 3: indicaciones de las principales cerámicas CAD-CAM en comercio.



Indicaciones				**Restauraciones de contorno completo**			**Estructuras**		
				Corona monolítica	**Puente monolítico de 3 unidades**	**Puente monolítico de múltiples unidades**	**Cofia de corona**	**Estructura de puente de 3 unidades**	**Estructura de puente de múltiples unidades**
Matriz vítrea	**Feldespática**		**CEREC Blocs C***	X					
			CEREC Blocs C PC*						
			CEREC Blocs C In*						
			VITABLOCS Mark II*						
			VITABLOCS TriLuxe forte*						
			VITABLOCS RealLife*						
		Reforzada con leucita	**Initial LRF Block***	X					
			IPS Empress CAD*						
		Reforzada con circonia	**Initial Zr-FS**						
	Silicato de litio	**Reforzado con circonia**	**VITA SUPRINITY PC**						
			Celtra Duo*	X					
	Disilicato de litio		**IPS e.max CAD***						
Policristalina	**Circonia**		**Cercon**	X	X	X	X	X	X
			inCoris ZI*				X		X
			inCoris TZI*	X		X			
			inCoris TZI C*	X		X			
			CEREC Zirconia*	X	X				
			CEREC Zirconia meso*						
			Initial Zirconia Disk						
			IPS e.max ZirCAD*	X		X	X		X
			IPS e.max ZirCAD Prime*	X	X	X	X	X	X
			M-ZR multilayer HT	X		X			
			M-ZR multilayer HT+	X	X				
			M-ZR multicolor ST	X	X	X			
			M-ZR color HT	X	X	X			
			M-ZR white HT	X		X			
			Katana Zirconia Block*	X	X				
			Katana Zirconia	X		X			
			NobelProcera Zirconia	X	X	X	X		X
			Nacera Pearl Shaded			X			X
			SHOFU Disk ZR Lucent	X	X	X	X	X	X
			VITA YZ*	X		X	X		X
			Lava Plus HT Zirconia Disc				X	X	
			Lava Zirconia Blocks*	X					
			3M Lava Esthetic Fluorescent Full-Contour Zirconia Disc	X					
			3M Chairside Zirconia*						
Matriz de resina	**Nanocerámica/Híbrida**		**CERASMART***						
			CERASMART270*						
			Katana Avencia Block*						
			SHOFU Block HC*	X					
			SHOFU Disk HC	X					
			VITA ENAMIC*				X		
			VITA ENAMIC IS				X		
			VITA ENAMIC multiColor						
			Lava Ultimate*						

* Disponible para *chairside*

Tabla 3: indicaciones de las principales cerámicas CAD-CAM en comercio.



Indicaciones				Prótesis implantosoportada						
				Superestructura implantosoportada	Corona atornillada	Puente atornillado	Corona con pilar híbrido	Pilar híbrido	Corona telescópica	Barra
Matriz vítrea	Feldespática		CEREC Blocs C*							
			CEREC Blocs C PC*							
			CEREC Blocs C In*							
			VITABLOCS Mark II*							
			VITABLOCS TriLuxe forte*							
			VITABLOCS RealLife*							
		Reforzada con leucita	Initial LRF Block*							
			IPS Empress CAD*							
		Reforzada con circonia	Initial Zr-FS							
	Silicato de litio	Reforzado con circonia	VITA SUPRINITY PC		X					
			Celtra Duo*							
	Disilicato de litio		IPS e.max CAD*							
Policristalina	Circonia		Cercon						X	
			inCoris ZI*						X	X
			inCoris TZI*							
			inCoris TZI C*						X	X
			CEREC Zirconia*							
			CEREC Zirconia meso*		X					
			Initial Zirconia Disk	X				X		
			IPS e.max ZirCAD*	X						
			IPS e.max ZirCAD Prime*							
			M-ZR multilayer HT							
			M-ZR multilayer HT+				X			
			M-ZR multicolor ST				X			
			M-ZR color HT				X			X
			M-ZR white HT				X			X
			Katana Zirconia Block*							
			Katana Zirconia							
			NobelProcera Zirconia		X	X				
			Nacera Pearl Shaded			X				
			SHOFU Disk ZR Lucent							
			VITA YZ*	X					X	
			Lava Plus HT Zirconia Disc		X	X				
			Lava Zirconia Blocks*					X	X	
			3M Lava Esthetic Fluorescent Full-Contour Zirconia Disc							
			3M Chairside Zirconia*							
Matriz de resina	Nanocerámica/Híbrida		CERASMART*		X					
			CERASMART270*		X					
			Katana Avencia Block*							
			SHOFU Block HC*		X					
			SHOFU Disk HC		X					
			VITA ENAMIC*		X					
			VITA ENAMIC IS		X					
			VITA ENAMIC multiColor							
			Lava Ultimate*							

* Disponible para *chairside*

Conclusiones

Las conclusiones son las siguientes:

- Como hemos visto dependiendo de la situación clínica se optará por un tipo de cerámica u otra. Las feldespáticas son indudablemente las mas estéticas y presentan una elevada tasa de supervivencia en restauraciones como *inlays*, *onlays* y coronas unitarias. De todos modos su baja resistencia centra sus indicaciones en el recubrimiento de estructuras, sin descartar alternativas monolíticas. Otras cerámicas de matriz vítrea, pero con mayor resistencia, son las de silicato de litio reforzado con circonia y disilicato de litio. Éste último en particular es el perfecto compromiso entre estética y resistencia, que le permite alcanzar reconstrucciones mas extensas (puentes de máximo 1 póntico). Gracias a sus características es uno de los materiales cerámicos más utilizados tanto en restauraciones multicapas como monolíticas. Otra porcelana ampliamente usada es la circonia que, careciendo de fase vítrea, se distingue por ser la mas resistente, llegando a soportar hasta 2 pónticos. Su composición le otorga un aspecto mas opaco, por lo que especialmente constituye el núcleo interno de prótesis multicapas. No obstante ha demostrado resultados monolíticos prometedores, aunque necesite un maquillado final. Los últimos materiales disponibles en el mercado CAD-CAM son las nanocerámicas las cuales han evidenciado una mayor facilidad de manejo (fresado, pulido, reparaciones). Sus indicaciones abarcan carillas, *inlays*, *onlays* y coronas unitarias (sobre todo como capa externa en las estratificadas, aunque algunas permiten restauraciones monolíticas).
- Cada vez mas clínicos se están convenciendo en seguir los avances tecnológicos implementando sistemas CAD-CAM en sus consultas. De hecho en los últimos años ha crecido notablemente el número de restauraciones monolíticas producidas "*in-office*" a través de sistemas *chairside*. Esto

se debe a los resultados proporcionados por este tipo de prótesis; menos problemas de fracturas, grietas, *chipping* y ausencia de *delamination*. No obstante todo, el número de materiales disponibles todavía es escaso. Además necesitan de un maquillado final con lo cual tampoco igualan la estética aportada por las restauraciones multicapa. Con respecto a éstas últimas, es cierto que presenten mayores inconvenientes de *chipping*, *debonding* y fracturas y que los tiempos de producción sean mas lentos. A la vez han demostrado mejores éxitos respecto a las estratificadas tradicionales y disponen de un rango de materiales considerablemente elevado. Se necesitan mas estudios clínicos de modo que las prótesis a contorno completo puedan reemplazar a las *multilayered*.

- Analizando 9 de las distintas casas comerciales que proporcionan materiales CAD-CAM al mundo de la odontología se denota que: 4 de ellas producen cerámicas de matriz de vidrio, sólo Ivoclar Vivadent comercializa disilicato de litio, todas fabrican circonia (Merz Dental GmbH y Nobel Biocare únicamente proporcionan óxido de circonio) y 5 confeccionan nanocerámicas. Además, todas procuran que por lo menos uno de sus materiales permita restauraciones monolíticas.

Responsabilidad

Este trabajo trata acerca de los últimos materiales cerámicos utilizados en odontología, limitándose a las porcelanas optimizadas para un empleo completamente digital (CAD-CAM). Esto significa que gracias a ellas, ya no es necesario tomar impresiones convencionales en alginato/siliconas, las cuales sucesivamente necesitarían un vaciado en escayola para poder trabajar sobre un modelo material. A través de un flujo de trabajo completamente informatizado ya es posible generar una cantidad mucho menor de residuos no reciclables. Desafortunadamente todavía es difícil reutilizar los desechos generados por las fresadoras. Esto significa que una mayor investigación sobre como recuperar los desperdicios generados por las maquinas quizás prosperaría la ecosostenibilidad. Por lo tanto, el presente trabajo trata un tema que podría beneficiar a la sostenibilidad medioambiental.

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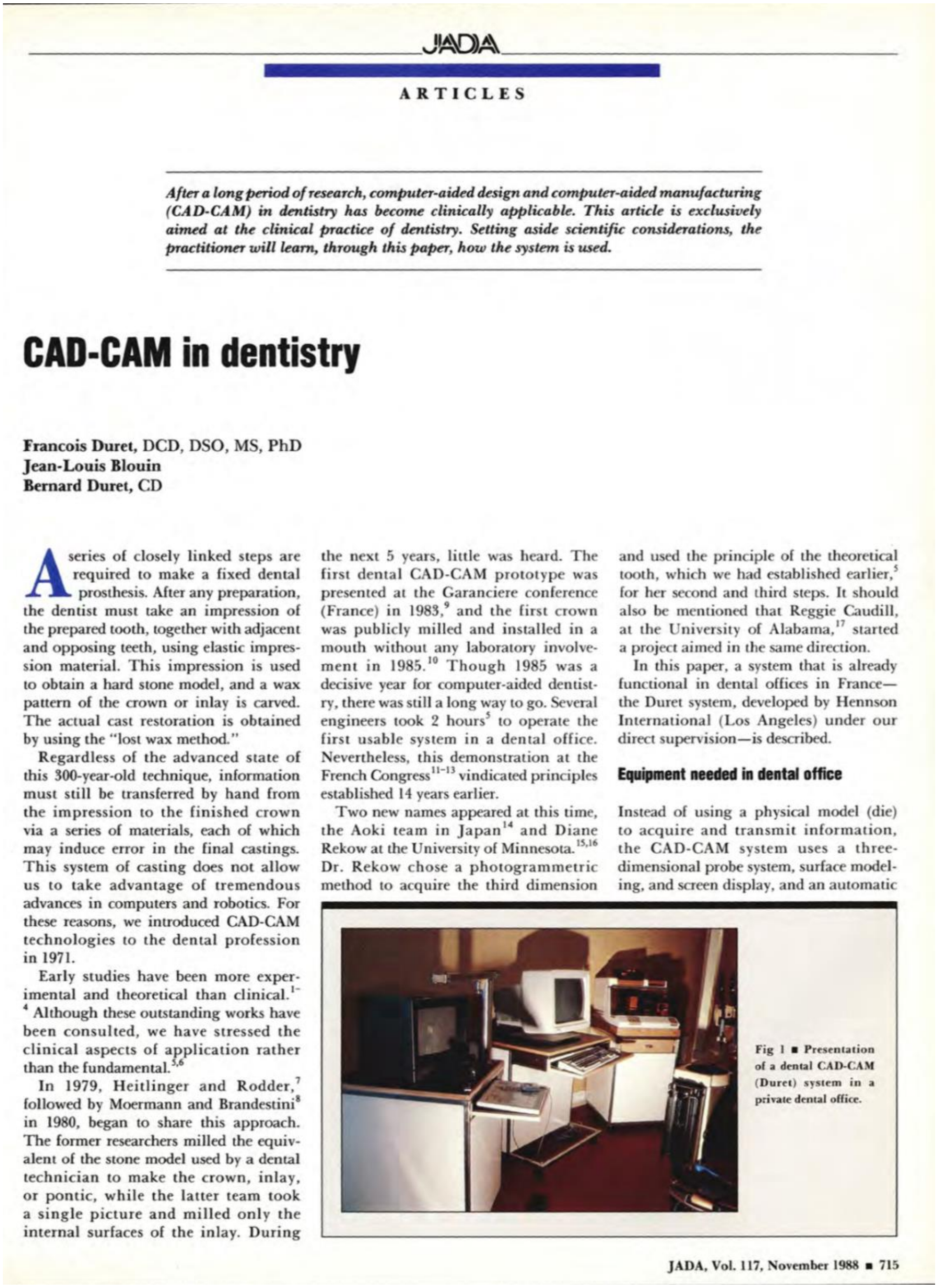
Anexos



JADA

ARTICLES

After a long period of research, computer-aided design and computer-aided manufacturing (CAD-CAM) in dentistry has become clinically applicable. This article is exclusively aimed at the clinical practice of dentistry. Setting aside scientific considerations, the practitioner will learn, through this paper, how the system is used.

CAD-CAM in dentistry

Francois Duret, DCD, DSO, MS, PhD
Jean-Louis Blouin
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A series of closely linked steps are required to make a fixed dental prosthesis. After any preparation, the dentist must take an impression of the prepared tooth, together with adjacent and opposing teeth, using elastic impression material. This impression is used to obtain a hard stone model, and a wax pattern of the crown or inlay is carved. The actual cast restoration is obtained by using the "lost wax method."

Regardless of the advanced state of this 300-year-old technique, information must still be transferred by hand from the impression to the finished crown via a series of materials, each of which may induce error in the final castings. This system of casting does not allow us to take advantage of tremendous advances in computers and robotics. For these reasons, we introduced CAD-CAM technologies to the dental profession in 1971.

Early studies have been more experimental and theoretical than clinical.[1-4] Although these outstanding works have been consulted, we have stressed the clinical aspects of application rather than the fundamental.[5,6]

In 1979, Heitlinger and Rodder,[7] followed by Moermann and Brandestini[8] in 1980, began to share this approach. The former researchers milled the equivalent of the stone model used by a dental technician to make the crown, inlay, or pontic, while the latter team took a single picture and milled only the internal surfaces of the inlay. During the next 5 years, little was heard. The first dental CAD-CAM prototype was presented at the Garanciere conference (France) in 1983,[9] and the first crown was publicly milled and installed in a mouth without any laboratory involvement in 1985.[10] Though 1985 was a decisive year for computer-aided dentistry, there was still a long way to go. Several engineers took 2 hours[5] to operate the first usable system in a dental office. Nevertheless, this demonstration at the French Congress[11-13] vindicated principles established 14 years earlier.

Two new names appeared at this time, the Aoki team in Japan[14] and Diane Rekow at the University of Minnesota.[15,16] Dr. Rekow chose a photogrammetric method to acquire the third dimension and used the principle of the theoretical tooth, which we had established earlier,[5] for her second and third steps. It should also be mentioned that Reggie Caudill, at the University of Alabama,[17] started a project aimed in the same direction.

In this paper, a system that is already functional in dental offices in France—the Duret system, developed by Hennson International (Los Angeles) under our direct supervision—is described.

Equipment needed in dental office

Instead of using a physical model (die) to acquire and transmit information, the CAD-CAM system uses a three-dimensional probe system, surface modeling, and screen display, and an automatic

Fig 1 ■ Presentation of a dental CAD-CAM (Duret) system in a private dental office.

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Journal of Prosthodontic Research 57 (2013) 236–261

Journal of Prosthodontic Research

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Review

Current status of zirconia restoration

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Received 27 August 2013; received in revised form 6 September 2013; accepted 6 September 2013
Available online 18 October 2013

Abstract

During the past decade, zirconia-based ceramics have been successfully introduced into the clinic to fabricate fixed dental prostheses (FDPs), along with a dental computer-aided/computer-aided manufacturing (CAD/CAM) system. In this article (1) development of dental ceramics, (2) the current status of dental CAD/CAM systems, (3) CAD/CAM and zirconia restoration, (4) bond between zirconia and veneering ceramics, (5) bond of zirconia with resin-based luting agents, (6) surface finish of zirconia restoration and antagonist enamel wear, and (7) clinical evaluation of zirconia restoration are reviewed.

Yttria partially stabilized tetragonal zirconia polycrystalline (Y-TZP) showed better mechanical properties and superior resistance to fracture than other conventional dental ceramics. Furthermore, ceria-stabilized tetragonal zirconia polycrystalline and alumina nanocomposites (Ce-TZP/A) had the highest fracture toughness and had resistance to low-temperature aging degradation. Both zirconia-based ceramics have been clinically available as an alternative to the metal framework for fixed dental prostheses (FDPs). Marginal adaptation of zirconia-based FDPs is acceptable for clinical application. The most frequent clinical complication with zirconia-based FDPs was chipping of the veneering porcelain that was affected by many factors. The mechanism for the bonding between zirconia and veneering ceramics remains unknown. There was no clear evidence of chemical bonding and the bond strength between zirconia and porcelain was lower than that between metal and porcelain.

There were two alternatives proposed that might avoid chipping of veneering porcelains. One was hybrid-structured FDPs comprising CAD/CAM-fabricated porcelain parts adhering to a CAD/CAM fabricated zirconia framework. Another option was full-contour zirconia FDPs using high translucent zirconia. Combined application of silica coating and/or silane coupler, and 10-methacryloyloxydecyl dihydrogen phosphate is currently one of the most reliable bonding systems for zirconia. Adhesive treatments could be applied to luting the restorations and fabricating hybrid-structured FDPs. Full-contour zirconia FDPs caused concern about the wear of antagonist enamel, because the hardness of Y-TZP was over double that of porcelain. However, this review demonstrates that highly polished zirconia yielded lower antagonist wear compared with porcelains. Polishing of zirconia is possible, but glazing is not recommended for the surface finish of zirconia.

Clinical data since 2010 are included in this review. The zirconia frameworks rarely got damaged in many cases and complications often occurred in the veneering ceramic materials. Further clinical studies with larger sample sizes and longer follow-up periods are required to investigate the possible influencing factors of technical failures.

Keywords: Dental CAD/CAM; FDPs; Zirconia; Polishing; Friction; Antagonist wear; Full contour

Contents

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http://dx.doi.org/10.1016/j.jpor.2013.09.001

The Use of CAD/CAM in Dentistry

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KEYWORDS

- CAD/CAM • CEREC • E4D • iTero • Lava COS
- Dental laboratory

Computer-aided design (CAD) and computer-aided manufacturing (CAM) have become an increasingly popular part of dentistry over the past 25 years.[1] The technology, which is used in both the dental laboratory and the dental office, can be applied to inlays, onlays, veneers, crowns, fixed partial dentures, implant abutments, and even full-mouth reconstruction. CAD/CAM is also being used in orthodontics.

CAD/CAM technology was developed to solve 3 challenges. The first challenge was to ensure adequate strength of the restoration, especially for posterior teeth. The second challenge was to create restorations with a natural appearance. The third challenge was to make tooth restoration easier, faster, and more accurate. In some cases, CAD/CAM technology provides patients with same-day restorations.

Dentists and laboratories have a wide variety of ways in which they can work with the new technology. For example, dentists can take a digital impression and send it to a laboratory for fabrication of the restorations or they can do their own computer-aided design and milling in-house.

When laboratories receive a digital impression, they can create a stone model from the data and either continue with traditional fabrication or rescan the model for milling. Alternatively, the laboratory can do all of the design work directly on the computer based on the images received.

This article discusses the history of CAD/CAM in dentistry and gives an overview of how it works. It also provides information on the advantages and disadvantages, describes the main products available, discusses how to incorporate the new technology into your practice, and addresses future applications.

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Dent Clin N Am 55 (2011) 559–570
doi:10.1016/j.cden.2011.02.011 dental.theclinics.com
0011-8532/11/$ – see front matter

Available online at www.sciencedirect.com
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Review

Advancements in CAD/CAM technology: Options for practical implementation

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ARTICLE INFO

Article history:
Received 26 October 2015
Received in revised form
10 December 2015
Accepted 16 January 2016
Available online xxx

Keywords:
CAD/CAM
Milling
3D printing
Scanner
Digital impression
Virtual articulator

ABSTRACT

Purpose: The purpose of this review is to present a comprehensive review of the current published literature investigating the various methods and techniques for scanning, designing, and fabrication of CAD/CAM generated restorations along with detailing the new classifications of CAD/CAM technology.

Study selection: I performed a review of a PubMed using the following search terms "CAD/CAM, 3D printing, scanner, digital impression, and zirconia". The articles were screened for further relevant investigations. The search was limited to articles written in English, published from 2001 to 2015. In addition, a manual search was also conducted through articles and reference lists retrieved from the electronic search and peer-reviewed journals.

Results: CAD/CAM technology has advantages including digital impressions and models, and use of virtual articulators. However, the implementation of this technology is still considered expensive and requires highly trained personnel. Currently, the design software has more applications including complete dentures and removable partial denture frameworks. The accuracy of restoration fabrication can be best attained with 5 axes milling units. The 3D printing technology has been incorporated into dentistry, but does not include ceramics and is limited to polymers. In the future, optical impressions will be replaced with ultrasound impressions using ultrasonic waves, which have the capability to penetrate the gingiva non-invasively without retraction cords and not be affected by fluids.

Conclusion: The coming trend for most practitioners will be the use of an acquisition camera attached to a computer with the appropriate software and the capability of forwarding the image to the laboratory.

Contents

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http://dx.doi.org/10.1016/j.jpor.2016.01.003
1883-1958/

Please cite this article in press as: Alghazzawi TF. Advancements in CAD/CAM technology: Options for practical implementation. J Prosthodont Res (2016), http://dx.doi.org/10.1016/j.jpor.2016.01.003

Received: 27 May 2019 | Revised: 20 August 2019 | Accepted: 22 September 2019
DOI: 10.1111/jerd.12535

WILEY

REVIEW ARTICLE

The potential of additive manufacturing technologies and their processing parameters for the fabrication of all-ceramic crowns: A review

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Abstract

Objective: This article aims to provide a review of the additive manufacturing technologies and the processing parameters that have been investigated for the fabrication of all ceramic crowns.

Overview: Additive manufacturing has crept its way into the field of dentistry for the fabrication of resin and metal prosthesis. To evaluate the current status of additive manufacturing for the fabrication of all ceramic crowns, literature review was targeted to include publications pertaining to the fabrication of dental ceramics and all ceramic crowns. With respect to the additive manufacturing of dental ceramics, five technologies have been investigated to date: stereolithography, material extrusion, powder based fusion, direct inkjet printing, and binder jetting. The processing parameters and experimental outcomes were collated and described for each of the aforementioned technologies.

Conclusion: Additive manufacturing has demonstrated promising experimental outcomes and corroborated to the fabrication all ceramic crowns. However, the technology is yet to witness a commercial breakthrough within this domain.

Clinical Significance: Additive manufacturing mitigates raw material wastage and tooling stresses that are associated with milling of ceramics. Continued research and development can lead to its approbation as an alternate technology for manufacturing all ceramic restorations.

KEYWORDS
3D printing, alumina, dental ceramics, dental porcelain, zirconia

1 | INTRODUCTION TO DIGITAL WORKFLOW

The exponential advancement in computer technology in the past few decades has led to a digital revolution in many industries by automizing the stages involved in production.[1] In the context of dentistry, it simply refers to the elimination of physical handling of specimens and subjecting them to computerized processing.[2,3] This approach has been termed as "digital workflow," a collective term that encompasses the three fundamental elements of digital dentistry, namely data acquisition, data processing, and data manufacturing.[3,4]

Acquisition of volumetric digital data is the first step in the digital workflow. This is simply a virtual impression of the oral and maxillofacial region. It requires the application of one of a variety of digitizers available that can generate a 3-dimensional (3D) scan/image.[5,6]

ABBREVIATIONS: AM, additive manufacturing; ASTM, American Society of Testing and Materials; BJ, binder jetting; CAD, computer aided design; DEP, direct energy deposition; DICOM, digital imaging and communications in medicine; DIP, direct inkjet printing; DLP, direct light processing; ME, material extrusion; MJ, material jetting; OBJ, object; PBF, powder based fusion; SL, sheet lamination; SLA, stereolithography; SM, subtractive manufacturing; STL, standard transformation language.

DENTAL MATERIALS 28 (2012) 3–12

Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

The future of dental devices is digital

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ARTICLE INFO

Article history:
Received 24 October 2011
Accepted 24 October 2011

Keywords:
Dental devices
CAD–CAM
Intra-oral scanners
Subtractive machining
Additive processing
FDM
SLA
SLM
Inkjet printing

ABSTRACT

Objectives. Major changes are taking place in dental laboratories as a result of new digital technologies. Our aim is to provide an overview of these changes. In this article the reader will be introduced to the range of layered fabrication technologies and suggestions are made how these might be used in dentistry.

Methods. Key publications in English from the past two decades are surveyed.

Results. The first digital revolution took place many years ago now with the production of dental restorations such as veneers, inlays, crowns and bridges using dental CAD–CAM systems and new improved systems appear on the market with great rapidity. The reducing cost of processing power will ensure that these developments will continue as exemplified by the recent introduction of a new range of digital intra-oral scanners. With regard to the manufacture of prostheses this is currently dominated by subtractive machining technology but it is inevitable that the additive processing routes of layered fabrication, such as FDM, SLA, SLM and inkjet printing, will start to have an impact. In principle there is no reason why the technology cannot be extended to all aspects of production of dental prostheses and include customized implants, full denture construction and orthodontic appliances. In fact anything that you might expect a dental laboratory to produce can be done digitally and potentially more consistently, quicker and at a reduced cost.

Significance. Dental device manufacturing will experience a second revolution when layered fabrication techniques reach the point of being able to produce high quality dental prostheses. The challenge for the dental materials research community is to marry the technology with materials that are suitable for use in dentistry. This can potentially take dental materials research in a totally different direction.

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0109-5641/$ – see front matter © 2011 Academy of Dental Materials. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.dental.2011.10.014

DENTAL MATERIALS 33 (2017) 84–98

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Chairside CAD/CAM materials. Part 1: Measurement of elastic constants and microstructural characterization

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ARTICLE INFO

Article history:
Received 24 October 2016
Accepted 26 October 2016

Keywords:
Ceramic
Resin composite
CAD/CAM
Chairside
Elastic modulus
Poisson's ratio
Microstructure

ABSTRACT

Objective. A deeper understanding of the mechanical behavior of dental restorative materials requires an insight into the materials elastic constants and microstructure. Here we aim to use complementary methodologies to thoroughly characterize chairside CAD/CAM materials and discuss the benefits and limitations of different analytical strategies.

Methods. Eight commercial CAM/CAM materials, ranging from 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) to hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE) have been selected. Elastic constants were evaluated using three methods: Resonant Ultrasound Spectroscopy (RUS), Resonant Beam Technique (RBT) and Ultrasonic Pulse-Echo (PE). The microstructures were characterized using Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy (EDX), Raman Spectroscopy and X-ray Diffraction (XRD).

Results. Young's modulus (E), Shear modulus (G), Bulk modulus (B) and Poisson's ratio (ν) were obtained for each material. E and ν reached values ranging from 10.9 (Lava Ultimate) to 201.4 (e.max ZirCAD) and 0.173 (Empress CAD) to 0.47 (Lava Ultimate), respectively. RUS showed to be the most complex and reliable method, while the PE method the easiest to perform but most unreliable. All dynamic methods have shown limitations in measuring the elastic constants of materials showing high damping behavior (hybrid materials). SEM images, Raman spectra and XRD patterns were made available for each material, showing to be complementary tools in the characterization of their crystal phases.

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http://dx.doi.org/10.1016/j.dental.2016.10.009

The Current State of Chairside Digital Dentistry and Materials

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KEYWORDS

• Chairside • CAD/CAM • Digital dentistry • Ceramics • Dental materials

KEY POINTS

- Chairside computer-aided design (CAD) computer-aided manufacturing (CAM) technologies have emerged into user-friendly and patient-friendly, versatile, and accurate clinical assets.
- Current intraoral scanning technologies are as accurate as, or even more accurate than, conventional impression techniques, at least for single-span and short-span multiunit restorations.
- Design software has been simplified with excellent features to produce natural esthetics and function.
- Milling machines have become smaller, more accurate, and more versatile for a large variety of materials.
- Most modern materials fabricated in the laboratory can also be fabricated chairside in a single visit: composite resins and various types of ceramics, even zirconia.

INTRODUCTION

Computer-aided design (CAD) computer-aided manufacturing (CAM) systems were initially developed in 1950 by the defense arm of the United States Air Force for use in aircraft and automotive manufacturing. It took 3 decades until such technologies were applied in dentistry, when Francois Duret developed a dental CAD/CAM device that included an optical impression of the abutment tooth and a numerically controlled milling machine.[1] The first restoration was milled in 1983 and the system demonstrated at the French Dental Association's International congress in November 1985. Werner Mormann is known as the developer of the first commercial CAD/CAM

Disclosure: The authors have nothing to disclose.

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Dent Clin N Am 63 (2019) 175–197
https://doi.org/10.1016/j.cden.2018.11.002
dental.theclinics.com

3D Volume Rendering and 3D Printing (Additive Manufacturing)

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Gerald T. Grant, DMD, MS[c]

KEYWORDS

- 3D printing • 3D volume rendering • Additive manufacturing • Rapid prototyping

KEY POINTS

- Three-dimensional (3D) volume rendering can be useful in volumetric assessment of bone defects; however, this still needs to be visualized on a computer monitor.
- 3D printing, additive manufacturing, and rapid prototyping techniques are being used in surgical planning with satisfactory accuracy.
- Categories of additive manufacturing techniques are discussed based on manufacturing process.
- 3D printing applications in dentistry and maxillofacial prosthetics are discussed.
- Limitations include time and cost; accuracy depends on type of 3D printer, material, and build thickness.

THREE-DIMENSIONAL VOLUME RENDERING

Volume rendering is a set of techniques used to display a 2-dimensional (D) projection of a 3D discretely sampled data set. These volume-rendered images can be sectioned in any plane and rotated in space, allowing 3D insight into the anatomy of craniofacial bones. 3D-rendered images provide additional information for surgical planning and teaching. Both multislice computed tomography and cone beam computed tomography (CBCT) have been shown as reliable techniques in the volumetric assessment of bone defects in alveolar and palatal regions.[1] With these techniques, accurate assessment of the size and extent of bone defects caused by oral clefts, for example, is possible. This is important not only in the treatment planning but also to establish

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Disclosure Statement: The authors have nothing to disclose.

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Dent Clin N Am 62 (2018) 393–402
https://doi.org/10.1016/j.cden.2018.03.003
dental.theclinics.com

dental materials xxx (2017) xxx–xxx

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Stereolithography: A new method for processing dental ceramics by additive computer-aided manufacturing

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ARTICLE INFO

Article history:
Received 7 July 2016
Received in revised form
23 January 2017
Accepted 30 January 2017
Available online xxx

Keywords:
Dental crown
Stereolithography
Ceramics
CAD/CAM
Additive technology

ABSTRACT

Objectives. The aim of this study was to compare the physical and mechanical properties of stereolithography (SLA)- manufactured alumina ceramics of different composition to those of subtractive- manufactured ceramics and to produce suitable dental crown frameworks.
Methods. The physical and mechanical properties of a control and six experimental SLA ceramics prepared from slurries with small (S) and large (L) particles (0.46 ± 0.03 and 1.56 ± 0.04 μm, respectively) and three dry matter contents (70%, 75%, 80%) were evaluated by dynamic rheometry, hydrostatic weighing, three3-point flexural strength measurements, and Weibull analyses, and by the micrometrics measurement of shrinkage ratio before and after the heat treatments.
Results. S75 was the only small particle slurry with a significantly higher viscosity than L70. The viscosity of the S80 slurry made it impossible to take rheological measurements. The viscosities of the S75 and S80 slurries caused deformations in the printed layers during SLA manufacturing and were excluded from further consideration. SLA samples with low dry matter content had significantly lower and densityflexural strengths. Only SLA samples with a large particle size and high dry matter content (L75 and L80) were similar in density and flexural strength to the subtractive- manufactured samples. The 95% confidence intervals of the Weibull modulus of the L80 ceramic were higher (no overlap fraction) than those of the L75 ceramic and were similar to the control (overlap fraction). The Weibull characteristics of L80 ceramic were higher than those of L75 ceramic and the control. SLA can be used to process suitable crown frameworks but shows results in anisotropic shrinkage.
Significance. The hH High particle size and dry matter content of the L80 slurry allowed made it possible to produce a reliable ceramic by SLA manufacturing with an anisotropic shrinkage, and a density, and flexural strength similar to those of a subtractive-manufactured ceramic. SLA allowed made it possible to build up a dense 3D alumina crown framework

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http://dx.doi.org/10.1016/j.dental.2017.01.018

Please cite this article in press as: Dehurtevent M, et al. Stereolithography: A new method for processing dental ceramics by additive computer-aided manufacturing. Dent Mater (2017), http://dx.doi.org/10.1016/j.dental.2017.01.018

A New Classification System for All-Ceramic and Ceramic-like Restorative Materials

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Nelson R.F.A. Silva, DDS, MSc, PhD[d]/Estevam A. Bonfante, DDS, MSc, PhD[e]

Classification systems for all-ceramic materials are useful for communication and educational purposes and warrant continuous revisions and updates to incorporate new materials. This article proposes a classification system for ceramic and ceramic-like restorative materials in an attempt to systematize and include a new class of materials. This new classification system categorizes ceramic restorative materials into three families: *(1)* glass-matrix ceramics, *(2)* polycrystalline ceramics, and *(3)* resin-matrix ceramics. Subfamilies are described in each group along with their composition, allowing for newly developed materials to be placed into the already existing main families. The criteria used to differentiate ceramic materials are based on the phase or phases present in their chemical composition. Thus, an all-ceramic material is classified according to whether a glass-matrix phase is present (glass-matrix ceramics) or absent (polycrystalline ceramics) or whether the material contains an organic matrix highly filled with ceramic particles (resin-matrix ceramics). Also presented are the manufacturers' clinical indications for the different materials and an overview of the different fabrication methods and whether they are used as framework materials or monolithic solutions. Current developments in ceramic materials not yet available to the dental market are discussed. *Int J Prosthodont 2015;28:227–235. doi: 10.11607/ijp.4244*

Ceramics have been the mainstay of esthetic dentistry for more than 100 years. Originally in the naturally occurring feldspathic form, ceramics were used primarily for anterior teeth as high fusing porcelain jacket crowns, denture teeth, and partial coverage. Beginning with John McLean's introduction of aluminous porcelain in the mid-1960s,[1] there have been continuous improvements in strength, esthetics, and methods of fabrication, resulting in dozens of products for clinicians to choose from.

Due to the high number of products available and the speed at which new products are being introduced, today's clinician faces a complex decision process when choosing a ceramic restorative material for a particular indication. The selection is seldom made on the basis of a thorough understanding of the materials' characteristics. More often, it is based on criteria such as strength measured in vitro, degree of translucency, manufacturing techniques, the preference of the dental laboratory technician, and even advertising claims.

A classification system of the ceramic materials used in dentistry is useful for a variety of purposes, including communication and education. Ideally, a classification system should be helpful in providing clinically relevant information about where to use the material (anterior versus posterior), for what type of restoration (partial versus full, short versus long-span), and how to lute it (adhesively versus traditionally). Different classification systems have been proposed that focus on clinical indications, composition, ability to be etched, processing methods, firing temperatures, microstructure, translucency, fracture resistance, and antagonist wear.[2–6] These classifications, however, tend to be either vague or imprecise, and they do not easily allow for the inclusion of new restorative materials.

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JOURNAL OF DENTISTRY 43 (2015) 726–734

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/jden

Colour parameters and shade correspondence of CAD–CAM ceramic systems

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ARTICLE INFO

Article history:
Received 7 October 2014
Received in revised form
21 January 2015
Accepted 26 February 2015

Keywords:
Colour
Dental ceramics
Reflectance

ABSTRACT

Objectives: To evaluate colour differences between (1) CAD–CAM ceramic systems considering shades A1, A2 and A3 and the corresponding nominal shade of VC (Vita Classical shade guide) and (2) shades A1–A2, A2–A3 and A1, A2 and A3 within the same ceramic system.

Methods: Samples of shades A1, A2 and A3 were fabricated ($n = 5$) from CAD–CAM ceramic blocks (IPS e.max® CAD LT and HT, IPS Empress® CAD LT and HT, Paradigm™ C, and VITABLOCS® Mark II) and polished to 1.0 ± 0.01 mm in thickness. Spectral reflectance and colour coordinates were measured using a spectroradiometer inside a viewing booth using the CIE D65 illuminant and the d/0° geometry. Spectral reflectance curves were compared using VAF coefficient and were statistically analyzed using Kruskal–Wallis and the Mann–Whitney *U* test ($\alpha = 0.05$). Colour coordinates were statistically analyzed using one-way ANOVA, Tukey's test with Bonferroni correction ($\alpha = 0.001$). All colour differences (ΔE^*_{ab} and ΔE_{00}) were analyzed through comparisons with the PT – perceptibility and AT – acceptability thresholds for dental ceramics.

Results: ΔE between ceramic systems and its corresponding shade ranged from 6.32 to 13.42 (ΔE^*_{ab}) and 4.48 to 9.30 (ΔE_{00}). ΔE between shades A1–A2, A2–A3 and A1, A2 and A3 ranged, respectively, 1.93–4.82, 1.22–5.59 and 3.63–8.84 (ΔE^*_{ab}); 1.54–3.87, 1.03–3.90 and 2.95–6.51 (ΔE_{00}).

Conclusions: Considering the corresponding nominal shade from VC, none of the ceramic systems showed colour differences below the AT. In addition, some ceramic systems showed colour differences below AT (shades A1–A2 and A2–A3) and below PT (shades A2–A3).

Clinical significance: Careful adjustments should be made to the final shade of CAD–CAM ceramic restorations to reach a clinically acceptable shade match.

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http://dx.doi.org/10.1016/j.jdent.2015.02.015
0300-5712/© 2015 Elsevier Ltd. All rights reserved.

Australian Dental Journal
The official journal of the Australian Dental Association

Australian Dental Journal 2011; 56:(1 Suppl): 84–96

doi: 10.1111/j.1834-7819.2010.01299.x

Ceramic materials in dentistry: historical evolution and current practice

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ABSTRACT

Dental ceramics are presented within a simplifying framework allowing for facile understanding of their development, composition and indications. Engineering assessments of clinical function are dealt with and literature is reviewed on the clinical behaviour of all-ceramic systems. Practical aspects are presented regarding the choice and use of dental ceramics to maximize aesthetics and durability, emphasizing what we know and how we know it.

Keywords: Ceramics, particle-filled glasses, polycrystalline ceramics, CAD/CAM, all-ceramic restorations.

Abbreviation: LTD = low temperature degradation.

CERAMICS IN DENTISTRY – WHERE DID THIS STUFF COME FROM?

It is quite useful reviewing how and why ceramics came to be used in dentistry. This account serves three purposes: (1) to alert practitioners to the fact that the use of ceramics, since the very beginning, always represented the adoption of 'high technology' versus 'craft art'; (2) to reinforce the concept that ceramics and improved ceramics were introduced in order to solve specific problems or to increase restorative versatility; and (3) to provide a gentle background into the nature and science of ceramics. Astute readers are also provided with clues as to where to watch for the emergence of new ceramic technologies.

Since a distinction was drawn between 'high technology' and 'craft art' it is useful to provide some basic defining characteristics of each. Many would agree that 'high technology' should include: (1) dentistry borrowing materials/processes shortly after their being developed by an unrelated industry; (2) incorporation of new learning from recent scientific literature outside of dental medicine; and (3) the spread of outright new inventions within dentistry. 'Craft art', on the other hand, brings to mind materials and techniques borrowed from those involved in jewellery making, the arts and the manufacture of everyday goods. All audiences the senior author has spoken to before have chosen 'craft art' as the likely source of ceramics introduced into dentistry at any stage of development.

In the early 1700s many European rulers were spending enormous sums importing porcelain from China and Japan. Figure 1, from Schloss Charlottenburg in Berlin, is representative of just small portions of one of these collections. The collection of Augustus III of Saxony was perhaps the largest and is now on display at the Zwinger Museum in Dresden, his former palace. Such activity led China to be characterized as being 'the bleeding bowl of Europe'. Between 1604 and 1657 alone, over three million pieces of Chinese porcelain reached Europe.[1] In 1700, 'East Indiamen' ships unloaded 146 748 pieces in a European port in just one day as the market for porcelain grew insatiable.[1]

One response to this situation involved state sponsored research into 'porcelain discovery'. Notable European leaders including Augustus (III) the Strong, King of Poland and Elector of Saxony along with the Medici family of Florence, Italy were independently sponsoring research into the development of a European porcelain to match the hard, translucent and sonorous material developed in eastern Asia nearly 1100 years earlier. Europeans strived at 'porcelain discovery' without much success for about 200 years and this activity is credited with being largely responsible for the growth of modern analytical chemistry

KEY WORDS
Ceramic, porcelain, lithium disilicate, zirconia

LEARNING OBJECTIVES

- To provide an overview of the various types of contemporary ceramic restorations
- To outline the benefits and limitations of contemporary ceramic restorative materials
- To provide information on the potential survival of ceramic dental restorations in different clinical situations

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Prim Dent J. 2019;8(3):28-33

DEMYSTIFYING MODERN DENTAL CERAMICS

ABSTRACT

With increasing patient expectation for aesthetic dental restorations, there has been a drive towards developing ceramic materials to meet this expectation. Multiple ceramic systems have been introduced over the past four decades with considerable advances in material properties. Survival rates of all-ceramic crowns differ by type of ceramic used, fabrication method and clinical indication. Zirconia and lithium disilicate are the most commonly used contemporary ceramic materials in dentistry. Survival data for these types of restorations appears to be promising; however, there is a lack of high-quality long-term clinical data on the success of these restorations. In the absence of robust longitudinal clinical research, laboratory studies have provided some useful information on the performance of ceramic restorations. Further high quality long-term clinical studies are needed to inform us of modes of failure of these restorations and the range of clinical circumstances in which each type of ceramic restoration may be used.

Introduction

Materials for indirect dental restorations can be broadly divided into three main categories: metal alloys (all-metal and metal-ceramic), all ceramic and resin-based composites. Of these restorative materials, it is widely accepted that cast gold alloy restorations provide extremely predictable long-term clinical service, with reported survival rates of 94.1% at 40 years.[1] Metal-ceramic restorations offer the advantage of combining good clinical longevity with reasonable aesthetic outcomes.[2,3] Over-time however, there has been an increasing patient expectation for higher aesthetic outcomes and metal-free restorations. This has led to a drive towards engineering and developing ceramic materials to meet this demand. Multiple ceramic systems have been introduced over the past four decades[4] with considerable advances in material properties. Survival rates of all-ceramic crowns differ by the type of ceramic used, fabrication method and clinical indication.[5,6]

Each type of ceramic material has its own advantages and limitations, and it is the clinician's responsibility to guide the patient as to which material will meet their functional and aesthetic needs. The aim of this paper is to provide an overview of the most common contemporary ceramics used in dentistry and outline their benefits and limitations.

DENTAL MATERIALS 35 (2019) 825–846

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.intl.elsevierhealth.com/journals/dema

Additive manufacturing of ceramics for dental applications: A review

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ARTICLE INFO

Article history:
Received 2 May 2018
Received in revised form
15 October 2018
Accepted 13 February 2019

Keywords:
Additive manufacturing
3D printing
Ceramics
Dentistry
Dental prosthesis

ABSTRACT

Objective. The main goal of this review is to provide a detailed and comprehensive description of the published work from the past decade regarding AM of ceramic materials with possible applications in dentistry. The main printable materials and most common technologies are also addressed, underlining their advantages and main drawbacks.

Methods. Online databases (Web of knowledge, Science Direct, PubMed) were consulted on this topic. Published work from 2008 to 2018 was collected, analyzed and the relevant papers were selected for inclusion on this review.

Results. Ceramic materials are broadly used in dentistry to restore/replace damaged or missing teeth, due to their biocompatibility, chemical stability and mechanical and aesthetic properties. However, there are several unmet challenges regarding their processing and performance. Due to their brittleness nature, a very tight control of the manufacturing process is needed to obtain dental pieces with adequate mechanical properties. Additive manufacturing (AM) is an emerging technology that constitutes an interesting and viable manufacturing alternative to the conventional subtractive methods. AM enables the production of customized complex 3D parts in a more sustainable and less expensive way. AM of ceramics can be achieved with an extensive variety of methods.

Significance. There is no perfect technology for all materials/applications, capable alone of fulfilling all the specificities and necessities of every patient. Although very promising, AM of ceramic dental materials remains understudied and further work is required to make it a widespread technology in dentistry.

Contents

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https://doi.org/10.1016/j.dental.2019.02.026

Received: 9 June 2019 | Revised: 6 October 2019 | Accepted: 16 December 2019
DOI: 10.1111/jerd.12566

WILEY

SPECIAL ISSUE ARTICLE

Materials in digital dentistry—A review

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Abstract

Objective: To review materials available in computer-aided design/computer-aided manufacturing (CAD/CAM), their various properties and accuracy are compared to conventional materials/methods when available.

Overview: CAD/CAM in dentistry is constantly growing and becoming a user- and patient-friendly technology and service using intraoral scanners and laboratory/chairside milling units to manufacture dental restorations and appliances from multiple materials including wax, metals, composite resins, and ceramics. Properties of these materials may vary when compared to restorations prepared from conventional and additive manufacturing methods. Understanding the differences in these properties is important for material and fabrication method selection. Additive manufacturing is becoming an alternative to subtractive manufacturing in many applications. However, chemical composition, mechanical and physical properties of these materials are still lacking. 3D printed materials require a considerable amount of research and time to prove their clinical efficacy.

Conclusion: The current developments in, and possibilities of, CAD/CAM technology is exciting and is transforming restorative dentistry. With all this excitement, it is crucially important to ensure that proper testing and evaluation of the various materials are warranted before making definite claims and decisions to replace conventionally prepared materials.

Clinical Significance: CAD/CAM materials are versatile and emerging as the material of choice for many restorations and appliances. For recently introduced CAD/CAM materials, it is important to ensure that proper clinical- and research-based evidence confirming the success and durability of these materials are available before recommending them in patient care.

KEYWORDS
additive manufacturing, CAD/CAM dentistry, dental materials, digital dentistry, subtractive manufacturing

1 | INTRODUCTION

Computer-aided design/computer-aided manufacturing (CAD/CAM) has been used for decades in industry and has increased in popularity over the past years in dentistry from making impressions, casts, and provisional fabrication to the final restorations.[1-3] Dental CAD/CAM systems consist of a scanner, software that processes the scanned data, and a fabrication system that transforms the data into an actual restoration, denture, or appliance. This "digital workflow" records both dentitions allowing the clinician to review and evaluate the tooth preparation and design a restoration that fulfills the intended treatment plan. A digital file can be uploaded to a cloud server for quick communication with the technician allowing any adjustment to be made before continuing to the next step. The process is usually time

The 3D-printed prototype: a new protocol for the evaluation and potential adaptation of monolithic all-ceramic restorations before finalization

Juan Legaz, DDS/Duygu Karasan, PhD, DDS/Vincent Fehmer, MDT/Irena Sailer, Prof Dr med dent

The prototyping protocol to evaluate and make the potential adjustments prior to finalization of the monolithic restorations was described by two clinical situations. In the first case report, following the digital impressions using an intraoral scanner (3Shape Trios, 3Shape) for an implant-supported four-unit fixed dental prosthesis, a digital design (3Shape Dental System, 3Shape) was performed and a prototype using subtractive CAM (milling) (PMMA, Telio CAD, Ivoclar Vivadent) was fabricated. The second case highlights the 3D-printed prototyping (additive CAM) (Sheraprint Model Plus UV, Shera) following digital impressions using an intraoral scanner and digital design in a patient requiring two opposing open-end three-unit fixed dental prostheses. By means of prototyping, the esthetic, fitting, and functional properties could be tested and the adjustments were completed on the prototypes. It is suggested that prototyping is an efficient tool that minimizes the clinical adjustment need for the final restoration while improving the communication between the dental practitioner and the technician. *(Quintessence Int 2020;51:538–544; doi: 10.3290/j.qi.a44635)*

Key words: CAD/CAM, ceramics, diagnostic procedure, digital workflow, prosthodontics

To achieve long-term success in restorative dentistry, comprehensive diagnostics and treatment planning followed by efficient communication among the dental practitioner, dental technician, and patient are crucial.[1-3] The evolution of dentistry in recent years has provided tools and materials to enhance the predictability and precision of the restorations by digital design,[4] allowing a wider range of manufacturing methods of the selected reconstructions and the associated materials.[5,6]

Based on systematic reviews, the estimated 5-year survival rates of multiple-unit fixed dental prostheses (FDPs) are reported as 94.4% for metal-ceramic and 90.4% for all-ceramic densely sintered zirconia when tooth-supported,[7] and as 98.7% for metal-ceramic and 93.0% for zirconia ceramic/monolithic zirconia when implant-supported.[8] Of the 5-year cumulative complication rates of zirconia ceramic, the most common technical complication was reported as fracture or chipping of the veneering material, with a rate of 50% (95% confidence interval [CI] 29.1% to 72.1%).[8]

There is a fundamental difference between the veneered and monolithic restorations when it comes to their adjustability.[9] Monolithic high-strength ceramic restorations demonstrate difficulty in clinical adjustment, which can lead to a potential loss in initial strength following the adjustments.[10] It was reported that micro-roughness, as a result of grinding on the surface of monolithic restorative materials, leads to crack propagation originating from those areas.[11,12] Thereby, this can jeopardize the mechanical superiority of those materials recommended for use in high stress-bearing areas.[11,12] Therefore, it is important to minimize the need for chairside adjustments of monolithic zirconia restorations. By means of the technologic developments and increased variety of material alternatives, fabricating prototypes by either additive or subtractive methods became viable. The esthetics, fit, and functional properties can be tested by these prototypes, prior to the fabrication of the definitive prostheses. Accordingly, the necessity of clinical adjustment may be minimized.

materials

MDPI

Review

Ceramic Materials and Technologies Applied to Digital Works in Implant-Supported Restorative Dentistry

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Received: 27 March 2020; Accepted: 20 April 2020; Published: 22 April 2020

Abstract: Computer-aided design and manufacturing technology has been closely associated with implant-supported restoration. The digital system employed for prosthodontic restorations comprises data acquisition, processing, and manufacturing using subtractive or additive methods. As digital implantology has developed, optical scanning, computer-based digital algorithms, fabricating techniques, and numerical control skills have all rapidly improved in terms of their accuracy, which has resulted in the development of new ceramic materials with advanced esthetics and durability for clinical application. This study reviews the application of digital technology in implant-supported dental restoration and explores two globally utilized ceramic restorative materials: Yttria-stabilized tetragonal zirconia polycrystalline and lithium disilicate glass ceramics.

Keywords: computer-aided design; analog-digital conversion; yttria-stabilized tetragonal zirconia; lithium disilicate; implant-supported dental prosthesis

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1. Introduction

A close association between computer-aided design (CAD)/computer-aided manufacturing (CAM) technology and implant dentistry has been developed since 1973, when Duret first performed dental restorative treatment using digital skills [1]. The CAD phase consists of data acquisition, design for provisional or definitive restoration, and implant installation planning based on the restorative design in a virtual space or using software. A subtractive milling machine cuts a block of restorative material to make the CAD product during the CAM phase, using cutting tools and the calculated paths of these tools. Recently, additive manufacturing technology has been introduced in various clinical dental fields and used to produce implant-supported restoration in digital works [2].

Some dental CAD/CAM systems are used to make prosthodontic restorations in clinicians' offices (in-office type), which are delivered to patients' mouths on the day of treatment [3]. Many dental CAD/CAM systems produce their products in dental laboratories (in-lab type). The in-office type of CAD/CAM system has a narrow range of applications limited to inlays, porcelain laminate veneers, and single crowns because of the conditions in the clinic [4,5]. However, as the in-office type is an all-in-one system containing data acquisition, processing, and manufacturing, many restorations have been made with this in-office CAD/CAM and used clinically [5,6]. The in-lab type produces not only single restorative modalities, but also long-span fixed dental prostheses replacing four, five, or even more missing teeth. Such a CAD/CAM system requires transfer of the oral data of a patient to the dental laboratory. A stone model is scanned using an extraoral scanner, while the digital impression technique with an intraoral scanner is employed for conventional impression-taking step in the clinic.

Received: 27 May 2019 | Revised: 20 August 2019 | Accepted: 22 September 2019
DOI: 10.1111/jerd.12535

REVIEW ARTICLE

WILEY

The potential of additive manufacturing technologies and their processing parameters for the fabrication of all-ceramic crowns: A review

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Abstract

Objective: This article aims to provide a review of the additive manufacturing technologies and the processing parameters that have been investigated for the fabrication of all ceramic crowns.

Overview: Additive manufacturing has crept its way into the field of dentistry for the fabrication of resin and metal prosthesis. To evaluate the current status of additive manufacturing for the fabrication of all ceramic crowns, literature review was targeted to include publications pertaining to the fabrication of dental ceramics and all ceramic crowns. With respect to the additive manufacturing of dental ceramics, five technologies have been investigated to date: stereolithography, material extrusion, powder based fusion, direct inkjet printing, and binder jetting. The processing parameters and experimental outcomes were collated and described for each of the aforementioned technologies.

Conclusion: Additive manufacturing has demonstrated promising experimental outcomes and corroborated to the fabrication all ceramic crowns. However, the technology is yet to witness a commercial breakthrough within this domain.

Clinical Significance: Additive manufacturing mitigates raw material wastage and tooling stresses that are associated with milling of ceramics. Continued research and development can lead to its approbation as an alternate technology for manufacturing all ceramic restorations.

KEYWORDS
3D printing, alumina, dental ceramics, dental porcelain, zirconia

1 | INTRODUCTION TO DIGITAL WORKFLOW

The exponential advancement in computer technology in the past few decades has led to a digital revolution in many industries by automizing the stages involved in production.[1] In the context of dentistry, it simply refers to the elimination of physical handling of specimens and subjecting them to computerized processing.[2,3] This approach has been termed as "digital workflow," a collective term that encompasses the three fundamental elements of digital dentistry, namely data acquisition, data processing, and data manufacturing.[3,4]

Acquisition of volumetric digital data is the first step in the digital workflow. This is simply a virtual impression of the oral and maxillofacial region. It requires the application of one of a variety of digitizers available that can generate a 3-dimensional (3D) scan/image.[5,6]

ABBREVIATIONS: AM, additive manufacturing; ASTM, American Society of Testing and Materials; BJ, binder jetting; CAD, computer aided design; DEP, direct energy deposition; DICOM, digital imaging and communications in medicine; DIP, direct inkjet printing; DLP, direct light processing; ME, material extrusion; MJ, material jetting; OBJ, object; PBF, powder based fusion; SL, sheet lamination; SLA, stereolithography; SM, subtractive manufacturing; STL, standard transformation language.

Critical Reviews in Oral Biology & Medicine

Journal of Dental Research
1–10

DOI: 10.1177/0022034518779759
journals.sagepub.com/home/jdr

CAD/CAM Ceramic Restorative Materials for Natural Teeth

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Abstract

Advances in computer-aided design (CAD) / computer-aided manufacturing (CAM) technologies and their ease of application enabled the development of novel treatment concepts for modern prosthodontics. This recent paradigm shift in fixed prosthodontics from traditional to minimally invasive treatment approaches is evidenced by the clinical long-term success of bonded CAD/CAM glass-ceramic restorations. Today, defect-oriented restorations, such as inlays, onlays, and posterior crowns, are predominately fabricated from glass-ceramics in monolithic application. The variety of CAD/CAM ceramic restorative systems is constantly evolving to meet the increased demands for highly aesthetic, biocompatible, and long-lasting restorations. Recently introduced polymer-infiltrated ceramic network CAD/CAM blocks add innovative treatment options in CAD/CAM chairside 1-visit restorations. The material-specific high-edge stability enables the CAD/CAM machinability of thin restoration margins. Full-contour zirconia restorations are constantly gaining market share at the expense of bilayered systems. Advancements in material science and bonding protocols foster the development of novel material combinations or fabrication techniques of proven high-strength zirconia ceramics. CAD/CAM applications offer a standardized manufacturing process resulting in a reliable, predictable, and economic workflow for individual and complex teeth-supported restorations. More evidence from long-term clinical studies is needed to verify the clinical performance of monolithic polymer-infiltrated ceramic network and zirconia teeth-supported minimally invasive and extensive restorations.

Keywords: computer-aided design, clinical outcomes, ceramics, prosthetic dentistry/prosthodontics, minimally invasive dentistry, aesthetics dental

Introduction

Computer-aided design (CAD) / computer-aided manufacturing (CAM) technology is one of the fastest-evolving aspects in modern restorative dentistry. The track record of CAD/CAM technology and chairside dentistry started in 1985, when Mörmann and Brandestini introduced the Cerec system.

An increasing number of chairside systems are now available (Zaruba and Mehl 2017). Intraoral scanners have become significantly better, faster, and smaller, with more intuitive design software surfaces. This virtual environment with on-screen designing and computer-assisted production with rapid prototyping, such as milling or the growing option of 3-dimensional printing possibilities, allows for the fabrication of various restorations without any physical models. Major advantages for the digital workflow over the conventional impression technique are patient's preferences as well as excellent marginal and internal fit of fixed prosthodontics (Chochlidakis et al. 2016; Gallardo et al. 2018). Due to the application of homogeneous industrial blanks and blocks, fewer material failures are likely to occur during fabrication and clinical application (Belli et al. 2017). In comparison with hand-built materials, CAD/CAM blocks reveal a decreased presence of flaws and pores, resulting in increased reliability (Zhang and Kelly 2017).

A large range of materials (Fig. 1) is currently available for the digital manufacturing process, increasing the range of indications in the field of restorative dentistry, dental implantology, orthodontics, and complex treatment-planning strategies. Hence, the decision to choose the right material for each indication has become challenging.

Consequently, the aim of this work is to review the evolution of CAD/CAD ceramic materials, to survey their respective properties, and to critically discuss the recent clinical evidence.

Evolution and State of the Art of CAD/CAM Ceramic Restorative Materials

Glass-Ceramics

Silica. The first CAD/CAM fine-structure feldspar ceramics (VITA Mark II; VITA-Zahnfabrik) evolved from traditional feldspathic ceramics and are still in clinical application (Table). The microstructural characterization of this feldspathic CAD/CAM ceramic reveals 2 crystallization patterns, with a sodium potassium aluminum silicate peak ($Al_8K_2Na_6O_34Si_9$) and a

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dental materials xxx (2016) xxx–xxx

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Chairside CAD/CAM materials. Part 2: Flexural strength testing

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ARTICLE INFO

Article history:
Received 24 October 2016
Accepted 26 October 2016
Available online xxx

Keywords:
Biaxial strength
B3B-test
4-point bending
CAD/CAM
Dental ceramics
Resin composites

ABSTRACT

Objective. Strength is one of the preferred parameters used in dentistry for determining clinical indication of dental restoratives. However, small dimensions of CAD/CAM blocks limit reliable measurements with standardized uniaxial bending tests. The objective of this study was to introduce the ball-on-three-ball (B3B) biaxial strength test for dental for small CAD/CAM block in the context of the size effect on strength predicted by the Weibull theory.

Methods. Eight representative chairside CAD/CAM materials ranging from 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) to hybrid materials (Enamic, VITA; Lava Ultimate, 3M ESPE) have been selected. Specimens were prepared with highly polished surfaces in rectangular plate ($12 \times 12 \times 1.2\,\mathrm{mm}^3$) or round disc ($Ø = 12\,\mathrm{mm}$, thickness $= 1.2\,\mathrm{mm}$) geometries. Specimens were tested using the B3B assembly and the biaxial strength was determined using calculations derived from finite element analyses of the respective stress fields. Size effects on strength were determined based on results from 4-point-bending specimens.

Results. A good agreement was found between the biaxial strength results for the different geometries (plates vs. discs) using the B3B test. Strength values ranged from 110.9 MPa (Vitablocs Mark II) to 1303.21 MPa (e.max ZirCAD). The strength dependency on specimen size was demonstrated through the calculated effective volume/surface.

Significance. The B3B test has shown to be a reliable and simple method for determining the biaxial strength restorative materials supplied as small CAD/CAM blocks. A flexible solution was made available for the B3B test in the rectangular plate geometry.

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http://dx.doi.org/10.1016/j.dental.2016.10.008

Please cite this article in press as: Wendler M, et al. Chairside CAD/CAM materials. Part 2: Flexural strength testing. Dent Mater (2016), http://dx.doi.org/10.1016/j.dental.2016.10.008

DENTAL-2743, No. of Pages9

ARTICLE IN PRESS

DENTAL MATERIALS XXX (2016) XXX-XXX

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Microstructure characterization and SCG of newly engineered dental ceramics

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ARTICLE INFO

Article history:
Received 8 June 2015
Received in revised form
23 November 2015
Accepted 22 March 2016
Available online xxx

Keywords:
Ceramics
Dental porcelain
Glass ceramics
Subcritical crack growth
Stress corrosion
Computer-aided design
Flexural strength
Young's modulus
Spectroscopy

ABSTRACT

Objectives. The aim of this study was to characterize the microstructure of four dental CAD-CAM ceramics and evaluate their susceptibility to stress corrosion.

Methods. SEM and EDS were performed for microstructural characterization. For evaluation of the pattern of crystallization of the ceramics and the molecular composition, XRD and FTIR, respectively, were used. Elastic modulus, Poisson's ratio, density and fracture toughness were also measured. The specimens were subjected to biaxial flexure under five stress rates (0.006, 0.06, 0.6, 6 and 60 MPa/s) to determine the subcritical crack growth parameters (n and D). Twenty-five specimens were further tested in mineral oil for determination of Weibull parameters. Two hundred forty ceramic discs (12 mm diameter and 1.2 mm thick) were made from four ceramics: feldspathic ceramic – FEL (Vita Mark II, Vita Zahnfabrik), ceramic-infiltrated polymer – PIC (Vita Enamic, Vita Zahnfabrik), lithium disilicate – LD (IPS e.max CAD, Ivoclar Vivadent) and zirconia-reinforced lithium silicate – LS (Vita Suprinity, Vita Zahnfabrik).

Results. PIC discs presented organic and inorganic phases ($n = 29.1 \pm 7.7$) and Weibull modulus (m) of 8.96. The FEL discs showed $n = 36.6 \pm 6.8$ and $m = 8.02$. The LD discs showed a structure with needle-like disilicate grains in a glassy matrix and had the lowest value of n (8.4 ± 0.8) and $m = 6.19$. The ZLS discs showed similar rod-like grains, $n = 11.2 \pm 1.4$ and $m = 9.98$.

Significance. The FEL and PIC discs showed the lowest susceptibility to slow crack growth (SCG), whereas the LD and ZLS discs presented the highest. PIC presented the lowest elastic

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http://dx.doi.org/10.1016/j.dental.2016.03.018

Please cite this article in press as: Ramos NdC, et al. Microstructure characterization and SCG of newly engineered dental ceramics. Dent Mater (2016), http://dx.doi.org/10.1016/j.dental.2016.03.018

Clin Oral Invest
DOI 10.1007/s00784-013-1173-2

ORIGINAL ARTICLE

Effect of selective enamel etching on clinical performance of CAD/CAM partial ceramic crowns luted with a self-adhesive resin cement

Marianne Federlin · Karl-Anton Hiller · Gottfried Schmalz

Received: 31 July 2013 / Accepted: 19 December 2013

Abstract

Objectives This study was conducted to evaluate a self-adhesive resin luting cement [RelyX Unicem 3MESPE–RXU] for luting partial ceramic crowns (PCCs) with and without selective enamel etching in a prospective, randomized clinical trial.

Materials and methods Thirty-four patients had received the intended treatment. Two PCCs (Vita Mark II; Cerec 3D; Sirona) had been placed in a split-mouth design: one with RXU without enamel etching (RXU), the other with RXU with selective enamel etching (RXU+E). Restorations were evaluated at baseline (BL) and after 12, 24, and 36 months (USPHS criteria). For statistical analysis, the Chi-square test was applied (α=0.05). Clinical survival of all restorations (n=68) after 3 years was determined using Kaplan–Meier analysis.

Results Twenty three patients (12 male/11 female) were available for clinical evaluation after 3 years. 19 RXU-PCCs were placed in molars, four in premolars, 18 RXU+E–PCCs in molars, five in premolars. Concerning clinical changes, no significant differences were found between luting strategies RXU/RXU+E at all recalls. Statistically significant changes over time were observed for *marginal adaptation* and *marginal discoloration* between BL and 36 m for RXU and RXU+E. For RXU+E, *postoperative hypersensitivities* decreased significantly from BL (n=6) to 36 m (n=0). Of the 68 restorations originally included, eight RXU and four RXU+E restorations failed. At 3 years, Kaplan–Meier survival of RXU was 72.9 %, that of RXU+E 87.6 %. Survival rates were not statistically significant different.

Conclusions Although clinical survival of RXU+E is slightly better at 3 years, restorations of both groups perform similar with respect to clinical changes over time as evaluated by modified USPHS criteria.

Clinical relevance The self-adhesive resin cement RXU can be used in conjunction with selective enamel etching, because survival rates of PCCs in the RXU+E group were not lower but, as a trend, even better than without enamel etching.

Keywords Controlled · Prospective clinical study · Partial ceramic crowns · Clinical evaluation · Self-adhesive cement · Selective enamel etching

Introduction

One major development in order to make the process of adhesive luting less technique-sensitive and time-consuming has been the introduction of self-adhesive universal luting materials in the beginning of the 21st century [12, 19, 29, 37]. As lined out by Stamatacos and Simon [37], self-adhesive universal luting materials can bond to an unconditioned tooth surface, respectively, the smear layer, without pretreatment with an acid or adhesive. Thus, incorporation of the restoration is accomplished in one single step. Self-adhesive resin cements contain phosphoric acid and/or carboxylic acid methacrylate monomers. After mixing, the phosphoric acid groups react with the hard tooth tissue, on the one hand, and with basic fillers incorporated in the luting material, on the other hand (cement reaction), thus forming a bond. Parallel to the cement reaction, polymerization of the methacrylate monomers is initiated (radical polymerization). While the material sets, the acid groups are neutralized, and it turns from hydrophilic to hydrophobic [17, 43]. The pretreatment of the ceramic restoration usually follows the ceramic manufacturer's recommendations

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THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL RESEARCH

A 3-year clinical evaluation of endodontically treated posterior teeth restored with two different materials using the CEREC AC chair-side system

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ABSTRACT

Statement of problem. The introduction of polymer-infiltrated ceramic network (PICN) materials may provide more options for dentists in restoring short clinical crowns and extensively damaged posterior teeth, but clinical data for their performance are lacking.

Purpose. The purpose of this clinical study was to compare the 3-year performance and survival rates of PICN material with those of conservative ceramic onlay restorations for endodontically treated posterior teeth using the CEREC AC chair-side system.

Material and methods. A total of 101 onlay restorations of endodontically treated posterior teeth using the CEREC AC chair-side system were provided in 93 participants. The 101 teeth were divided into 2 groups: Vita Enamic group and Vitablocs Mark II group. Using the modified US Public Health Service quality evaluation system, 2 calibrated evaluators examined the performance of the onlay restorations over 3 years. The Kaplan-Meier method was adopted to analyze the survival rate of restorations (α=.05). The log rank test was used to compare the survival rates of the 2 groups. The Fisher exact test was performed to detect differences in the success rates for extensively damaged teeth and short clinical crown restorations between the 2 groups. The Silness and Löe gingival index was also recorded.

Results. The restoration survival rates in the 2 groups were 97.0% (Vita Enamic) and 90.7% (Vitablocs Mark II) (P>.05). Five failures were recorded (4.95%). These failures were caused by restoration debonding (60%), ceramic fractures (20%), and tooth fractures (20%). There were no significant differences between the success rates of restoring extensively damaged teeth and short clinical crowns between the 2 groups (P>.05). The periodontal condition of 25% of participants was improved 3 years after the onlay restorations.

Conclusions. Onlay restorations of endodontically treated posterior teeth with Vita Enamic using the CEREC AC chair-side system are clinically promising prosthodontic alternatives, with a survival rate of 97.0% after 3 years. More research is needed to verify the results of this study. (J Prosthet Dent 2017;■:■-■)

Chairside immediate ceramic restorations make use of computer-aided design and computer-aided manufacturing (CAD-CAM) to complete the restoration fabrication process in a single visit. This technique has become popular and led prosthetic dentistry into a digital era.[1] CEREC AC (Dentsply Sirona) was first introduced in 2009. The CEREC AC Bluecam uses blue wavelength light and allows dentists to produce virtual models of a higher resolution than with those of the earlier CEREC Acquisition unit system.[2]

The fracture rate of endodontically treated teeth is higher than that of vital teeth.[3] An onlay is an indirect restoration retained by intracoronal boxes (vital teeth) or extended into the pulp chamber (nonvital teeth) that covers the occlusal surface.[4] Onlay restorations not only restore the tooth structure, but can provide optimal

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Supported by National Natural Science Foundation of China (grant 81371137). T.L. and L.P. contributed equally to this work.

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THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL RESEARCH

Monolithic CAD-CAM lithium disilicate versus monolithic CAD-CAM zirconia for single implant-supported posterior crowns using a digital workflow: A 3-year cross-sectional retrospective study

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Giuseppe D'Amato, DDS,[e] and Silvio De Angelis, DDS[f]

ABSTRACT

Statement of problem. Dentistry has evolved significantly with the introduction of digital technologies and materials; however, clinical evidence for the performance of the complete digital workflow for single implant–supported posterior crowns is lacking.

Purpose. The purpose of this cross-sectional retrospective clinical study was to compare the clinical outcomes of 2 types of implant-supported crown used to replace a single missing posterior tooth in a completely digital workflow: transocclusal screw-retained monolithic lithium disilicate crowns versus transocclusal screw-retained monolithic zirconia crowns.

Material and methods. A total of 38 participants who had been provided with dental implants and transocclusal screw-retained monolithic lithium disilicate or zirconia single crowns were evaluated in the study. Clinical and esthetic outcomes were recorded after a 3-year follow-up.

Results. Both groups had comparable clinical outcomes with a survival rate of 100%. In the lithium disilicate group, 89% of the participants were free of technical complications, and 95%, in the zirconia group. Only 1 patient experienced minor chipping affecting a lithium disilicate crown. All complications were considered minor and were easily resolved, and none of the participants required replacement of a crown. No biological complications were recorded in either group.

Conclusions. Within the limitations of this cross-sectional retrospective clinical study, monolithic lithium disilicate and zirconia screw-retained single crowns fabricated using computer-aided design and computer-aided manufacturing (CAD-CAM) and a fully digital workflow were found to be reliable and suitable clinical options for restoring a posterior missing tooth on a dental implant. (J Prosthet Dent 2019;■:■-■)

Among the new digital technologies introduced to prosthodontics and restorative dentistry is computer-aided design and computer-aided manufacturing (CAD-CAM).[1-5] The introduction of monolithic materials with CAD-CAM technology has ensured high biocompatibility, better esthetics, and improved biomechanical properties over traditional materials.[3,6] Nevertheless, the traditional approach, which uses conventional impressions and stone casts to fabricate metal-ceramic restorations by the lost-wax technique, has well-established long-term outcomes and reliability.[1,7]

Recently, lithium disilicate and monolithic zirconia have become popular materials for the fabrication of implant-supported crowns, with lithium disilicate providing higher translucency and lower mechanical strength than zirconia.[8,9] Complications with implant restorations can be divided into technical (loss of retention, fracture of porcelain, framework or secondary parts, and screw loosening) and biological (peri-implant radiolucencies, signs of peri-implantitis). To validate the use of these monolithic materials for screw-retained

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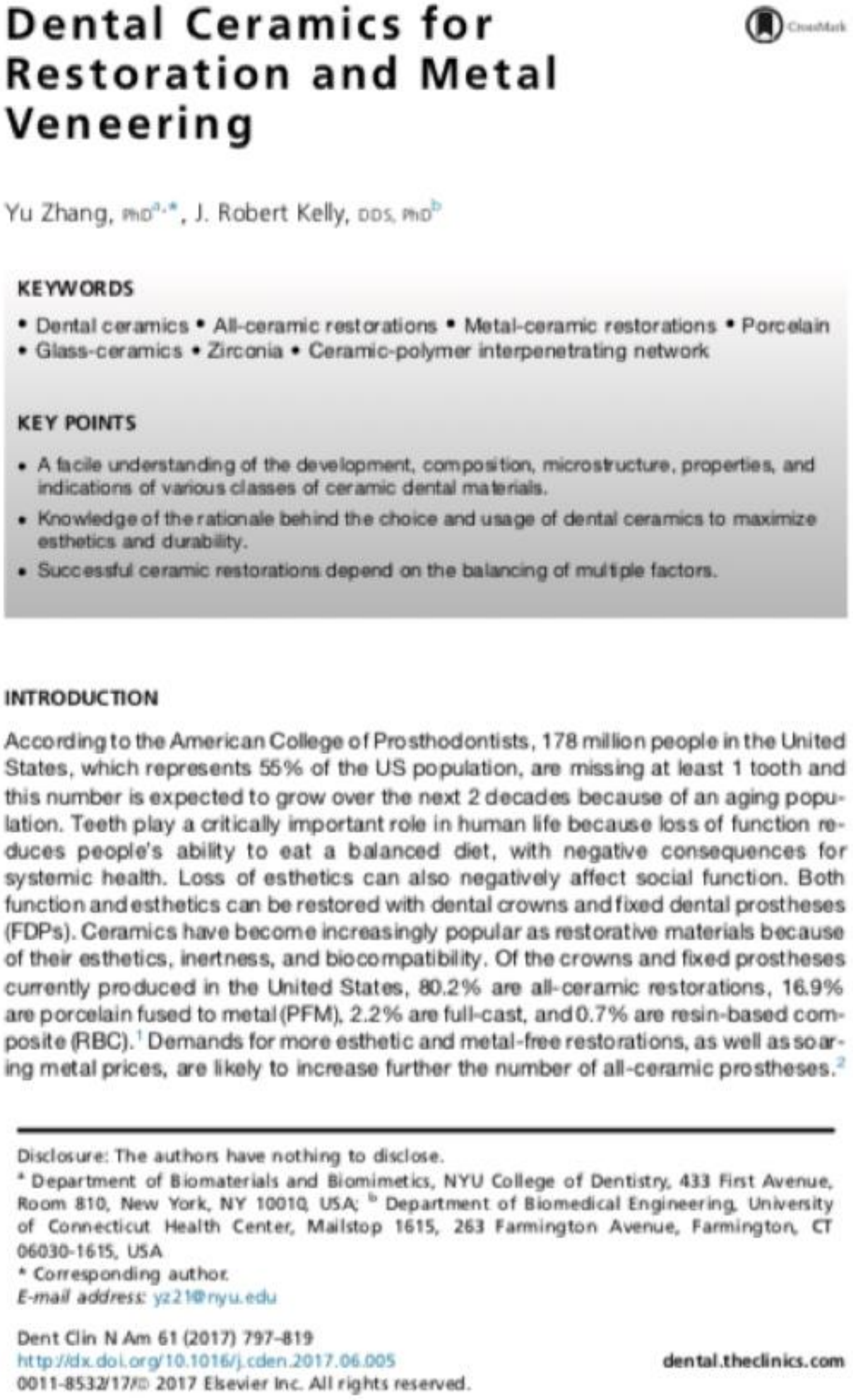

Dental Ceramics for Restoration and Metal Veneering

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KEYWORDS

- Dental ceramics • All-ceramic restorations • Metal-ceramic restorations • Porcelain
- Glass-ceramics • Zirconia • Ceramic-polymer interpenetrating network

KEY POINTS

- A facile understanding of the development, composition, microstructure, properties, and indications of various classes of ceramic dental materials.
- Knowledge of the rationale behind the choice and usage of dental ceramics to maximize esthetics and durability.
- Successful ceramic restorations depend on the balancing of multiple factors.

INTRODUCTION

According to the American College of Prosthodontists, 178 million people in the United States, which represents 55% of the US population, are missing at least 1 tooth and this number is expected to grow over the next 2 decades because of an aging population. Teeth play a critically important role in human life because loss of function reduces people's ability to eat a balanced diet, with negative consequences for systemic health. Loss of esthetics can also negatively affect social function. Both function and esthetics can be restored with dental crowns and fixed dental prostheses (FDPs). Ceramics have become increasingly popular as restorative materials because of their esthetics, inertness, and biocompatibility. Of the crowns and fixed prostheses currently produced in the United States, 80.2% are all-ceramic restorations, 16.9% are porcelain fused to metal (PFM), 2.2% are full-cast, and 0.7% are resin-based composite (RBC).[1] Demands for more esthetic and metal-free restorations, as well as soaring metal prices, are likely to increase further the number of all-ceramic prostheses.[2]

Disclosure: The authors have nothing to disclose.

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Dent Clin N Am 61 (2017) 797–819
http://dx.doi.org/10.1016/j.cden.2017.06.005
dental.theclinics.com

Clinical outcomes of lithium disilicate glass-ceramic crowns fabricated with CAD/CAM technology: A systematic review

Ocena kliniczna koron szklano-ceramicznych z dwukrzemianu litu wytwarzanych w technologii CAD/CAM – systematyczny przegląd piśmiennictwa

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online)

Dent Med Probl. 2020;57(2):197–206

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Funding sources
None declared

Conflict of interest
None declared

Received on October 29, 2019
Reviewed on November 26, 2019
Accepted on December 19, 2019

Abstract

The use of ceramic materials and the computer-aided design/computer-aided manufacturing (CAD/CAM) technology for the fabrication of complete-coverage restorations has significantly increased in the last decade. The aim of this study was to evaluate the survival rate of anterior and posterior monolithic and bilayered lithium disilicate glass-ceramic (LDGC) CAD/CAM crowns, and to identify the types of complications associated with the main clinical outcomes reported in clinical trials. MEDLINE/PubMed, Embase, Scopus, Web of Science, Cochrane Library, and ClinicalTrials.gov were searched by 2 independent reviewers for clinical studies published between 2006 and 2019, following the Preferred Reporting Items for Systematic Reviews and *Meta-Analyses* (PRISMA) statement. The electronic search was supplemented by a hand search. Quality assessment for the included studies was performed. Qualitative and quantitative data was extracted from each study. Out of 219 studies, 6 studies that evaluated LDGC CAD/CAM crowns were identified and used for data extraction. The included studies had 154 participants, who received 204 crowns.

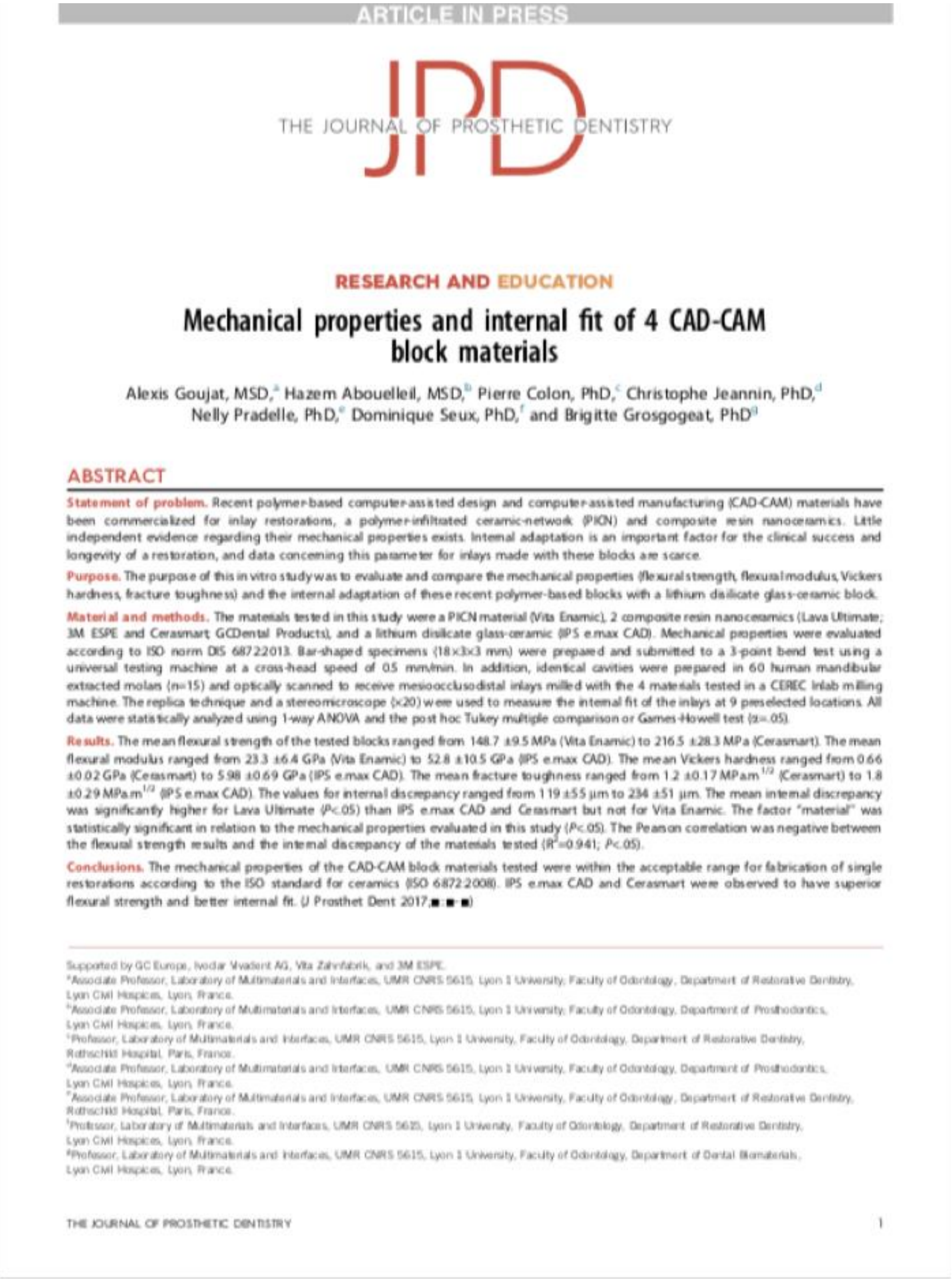
The short- to medium-term survival and success rates were high. Biological complications occurred more frequently than technical complications. No esthetic complications were reported. This review indicated that the medium-term survival rate of LDGC CAD/CAM crowns was high. Further multicenter studies with longer follow-ups and larger sample sizes are needed in order to augment the data already in existence.

Key words: survival, glass-ceramic, prosthodontics, dental porcelain, computer-aided design/computer-aided manufacturing

Słowa kluczowe: przetrwanie, szklano-ceramiczne, protetyka stomatologiczna, ceramika stomatologiczna, komputerowo wspomagane projektowanie i produkcja

Cite as
Aziz A, El-Mowafy O, Paredes S. Clinical outcomes of lithium disilicate glass-ceramic crowns fabricated with CAD/CAM technology: A systematic review. *Dent Med Probl.* 2020;57(2):197–206. doi:10.17219/dmp/115522

DOI
10.17219/dmp/115522



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THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Mechanical properties and internal fit of 4 CAD-CAM block materials

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Nelly Pradelle, PhD,[e] Dominique Seux, PhD,[f] and Brigitte Grosgogeat, PhD[g]

ABSTRACT

Statement of problem. Recent polymer-based computer-assisted design and computer-assisted manufacturing (CAD-CAM) materials have been commercialized for inlay restorations, a polymer-infiltrated ceramic-network (PICN) and composite resin nanoceramics. Little independent evidence regarding their mechanical properties exists. Internal adaptation is an important factor for the clinical success and longevity of a restoration, and data concerning this parameter for inlays made with these blocks are scarce.

Purpose. The purpose of this in vitro study was to evaluate and compare the mechanical properties (flexural strength, flexural modulus, Vickers hardness, fracture toughness) and the internal adaptation of these recent polymer-based blocks with a lithium disilicate glass-ceramic block.

Material and methods. The materials tested in this study were a PICN material (Vita Enamic), 2 composite resin nanoceramics (Lava Ultimate; 3M ESPE and Cerasmart; GCDental Products), and a lithium disilicate glass-ceramic (IPS e.max CAD). Mechanical properties were evaluated according to ISO norm DIS 6872:2013. Bar-shaped specimens (18×3×3 mm) were prepared and submitted to a 3-point bend test using a universal testing machine at a cross-head speed of 0.5 mm/min. In addition, identical cavities were prepared in 60 human mandibular extracted molars (n=15) and optically scanned to receive mesioocclusodistal inlays milled with the 4 materials tested in a CEREC Inlab milling machine. The replica technique and a stereomicroscope (×20) were used to measure the internal fit of the inlays at 9 preselected locations. All data were statistically analyzed using 1-way ANOVA and the post hoc Tukey multiple comparison or Games-Howell test (α=.05).

Results. The mean flexural strength of the tested blocks ranged from 148.7 ±9.5 MPa (Vita Enamic) to 216.5 ±28.3 MPa (Cerasmart). The mean flexural modulus ranged from 23.3 ±6.4 GPa (Vita Enamic) to 52.8 ±10.5 GPa (IPS e.max CAD). The mean Vickers hardness ranged from 0.66 ±0.02 GPa (Cerasmart) to 5.98 ±0.69 GPa (IPS e.max CAD). The mean fracture toughness ranged from 1.2 ±0.17 MPa.m$^{1/2}$ (Cerasmart) to 1.8 ±0.29 MPa.m$^{1/2}$ (IPS e.max CAD). The values for internal discrepancy ranged from 119 ±55 μm to 234 ±51 μm. The mean internal discrepancy was significantly higher for Lava Ultimate (P<.05) than IPS e.max CAD and Cerasmart but not for Vita Enamic. The factor "material" was statistically significant in relation to the mechanical properties evaluated in this study (P<.05). The Pearson correlation was negative between the flexural strength results and the internal discrepancy of the materials tested (R^2=0.941; P<.05).

Conclusions. The mechanical properties of the CAD-CAM block materials tested were within the acceptable range for fabrication of single restorations according to the ISO standard for ceramics (ISO 6872:2008). IPS e.max CAD and Cerasmart were observed to have superior flexural strength and better internal fit. (J Prosthet Dent 2017;■:■-■)

Supported by GC Europe, Ivoclar Vivadent AG, Vita Zahnfabrik, and 3M ESPE.

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Fracture Toughness, Flexural Strength, and Flexural Modulus of New CAD/CAM Resin Composite Blocks

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Keywords
fracture mechanics; CAD/CAM; resin composite; lithium disilicate; fractography.

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Dr. Iben J.R. Lucsanszky completed the work presented in this study in partial fulfillment of the requirement for the Diploma in Prosthodontics and Master of Science in the Faculty of Dentistry and Faculty of Graduate and Postdoctoral Studies (Craniofacial Science), University of British Columbia, Vancouver, Canada.

(https://open.library.ubc.ca/media/stream/pdf/24/1.0376459/4)

The paper was presented as a poster during the 2018 AADR meeting.

The authors deny any conflicts of interest in regards to the current study.

Accepted November 4, 2019

doi: 10.1111/jopr.13123

Abstract

Purpose: To determine and compare the fracture toughness, flexural strength and flexural modulus of four new, commercially available CAD/CAM resin composite blocks and one new CAD/CAM lithium disilicate glass-ceramic block, tested under dry and aged conditions.
Materials and Methods: Three dispersed-fillers resin composite blocks, CERASMART, KZR-CAD-HR2, and CAMouflage NOW, one polymer-infiltrated ceramic network resin composite block, Enamic, along with Obsidian, a lithium disilicate glass-ceramic block, were characterized. Fracture toughness was determined through the notchless triangular prism specimen test, while flexural strength and flexural modulus were determined by three-point bend testing. Blocks were cut and ground to obtain (6 × 6 × 6 × 12) mm prisms and 10:1 span-to-thickness ratio bars ($n = 25$/group); half of the resin composite specimens were aged in 37°C distilled water for 30 days before testing. Fractured surfaces were characterized using a scanning electron microscope. Results were analyzed using Weibull statistics and two-way ANOVA, followed by Scheffé multiple means comparisons ($\alpha = 0.05$).
Results: With regards to fracture toughness, KZR stood out among resin composites with a dry value of 1.37 MPa m$^{1/2}$; this was significantly affected by ageing, while the fracture toughness of the other dispersed-fillers resin composite blocks was not. Obsidian had the highest fracture toughness at 1.47 MPa m$^{1/2}$. With regards to flexural strength, Obsidian > CERASMART = KZR > CAMouflage > Enamic. The flexural strength of the resin composites was lowered by ageing. Enamic was found to have the highest flexural modulus among the resin composites (33.02 GPa), but its value was significantly lower than that of Obsidian (76.46 GPa); flexural modulus was not affected by ageing.
Conclusion: There was a significant difference in flexural strength between the materials, but not unanimously in flexural modulus and fracture toughness. The tested resin composite block materials had inferior flexural strength, flexural modulus and fracture toughness compared with the tested lithium disilicate glass-ceramic block (Obsidian). Enamic, the polymer infiltrated ceramic network material, had a significantly higher flexural modulus than the dispersed-fillers materials. Ageing had a deleterious impact on the flexural strength of all RCB, while its effect on the flexural modulus was insignificant. The selection of any restorative material requires a thorough analysis of its advantages and limitations to inform the clinical decision in a case-by-case approach.

With the expansion of computer-aided design/computer-aided manufacturing (CAD/CAM) technology in dentistry, the development of new restorative CAD/CAM materials has increased significantly over the last two decades.[1] The manufacturing processes of these materials occur in an industrial environment, with higher levels of control and reproducibility. Ceramic/glass-ceramic and resin composite CAD/CAM milling blocks can be machined chairside into good quality, digitally custom-designed restorations. Due to suitable characteristics, ceramic/glass-ceramic CAD/CAM blocks are still more commonly used clinically;[2] however, interest in resin composite blocks (RCB) has recently increased.[3] Their excellent machinability, edge stability and reduced brittleness mitigated some of the disadvantages encountered with ceramic/glass-ceramic blocks.[4] However, there is a scarcity of independent confirmation of their key properties (identified as potential clinical

Dental Materials Journal 2020; : –

Flexural strength and fracture toughness of two different lithium disilicate ceramics

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To test the impact of the pressing furnace on flexural strength and facture toughness of the lithium-disilicate-ceramics HS10PC (HS) and IPS e.max Press (IP). Three hundred and sixty specimens (3×4×30 mm) were pressed (n=180/ceramic) using different pressing furnaces, namely Austromat 654 Press-i-dent (AUS), Programat EP5000 (PRO), and Vario Press 300 (VAR). Three-point flexural strength (n=30) and fracture toughness (n=30) were measured. Flexural strength (336–360 MPa) was not affected by pressing furnace or ceramic and showed comparable values between all groups. Fracture toughness (2.65–2.81 MPa$\sqrt{\text{m}}$) provided higher values for HS pressed using AUS compared to specimens pressed in PRO and VAR. For IP, no impact of the pressing furnace on fracture toughness was found. IP presented higher fracture toughness than HS when pressed using PRO. No correlations were found. Both lithium disilicate ceramics showed comparable flexural strength regardless of the pressing furnace. Fracture toughness depended on the ceramic and on the pressing furnace.

Keywords: Lithium disilicate ceramic, Glass-ceramic, Flexural strength, Fracture toughness, Pressing furnace

INTRODUCTION

Glass-ceramics show favorable mechanical and biological properties, such as flexural strength, fracture load, low thermal conductivity and minimal plaque accumulation[1-8]. Ceramics differ in their composition. Their mechanical and optical properties are influenced by their composition and crystalline structure[5,9]. For lithium disilicate, ceramics, the molar ratio of Li_2O and SiO_2 is essential for example for the formation of Li_2SiO_3, $Li_2Si_2O_5$ or Li_4SiO_4. An increase in the crystalline structure of up to 60–70% through a reinforcement of lithium disilicate, lithium silicate or lithium orthophosphate ($Li_2Si_2O_5$, Li_2SiO_3, Li_3PO_4) crystals, leads to glass-ceramics with a flexural strength about 2–3 times higher than that of unreinforced glass-ceramics[1,2-5,7,10-12]. Processing can influence the crystals share and amount, as well as the type and the orientation of the crystals, porosities, and shrinkage. This influence the mechanical properties such as flexural strength or fracture toughness. The variation of processing parameters such as temperature and holding time is used for controlling the crystal growth and content and type of crystals, allowing an individual adjustment of the mechanical properties of the ceramic. Therefore, variations of the processing parameters are supposed to affect the consistent material properties and variations.

The pressing of lithium disilicate ceramics with the lost wax technique combines a good marginal fit, an occlusal accuracy, low shrinkage, low porosity, good mechanical properties, and is above all, a simple and cost-effective fabrication method[3,4,13-14]. Pressed lithium disilicate ceramic resulted in superior fracture toughness compared to milled ceramics[15,16]. These observations might be traced back to different heating parameters that are known to possibly upset the driving force for growing lithium disilicate crystals and alter the overall percentage of residual glasses, which in turn might adversely impact several material properties including load-bearing capacity and fracture toughness[17].

Glass-ceramics can be pressed with different pressing furnaces. Not every manufacturer has a complete system, including ceramic and pressing furnace. And not every ceramic manufacturer specifies the pressing program for all furnaces available on the market. Manufacturers are either focusing on furnace construction or material development. However, investigations analyzing the influence of the pressing furnace on the mechanical properties of lithium disilicate ceramics could not yet be found in literature.

Therefore, the aim of this study was to elaborate the pressing parameters for the respective furnaces and two different lithium disilicate ceramics as a first step. The second aim was to examine the influence of three different pressing furnaces on flexural strength (3-point-flexural-strength) and fracture toughness (single-edge-V-notch-beam; SEVNB) of the ceramics. The first part of the hypothesis stated that both ceramics show similar flexural strength regardless of the pressing furnace while the second part stated that the fracture toughness results of both tested lithium disilicate ceramics are comparable irrespective of the pressing furnace used.

Color figures can be viewed in the online issue, which is available at J-STAGE.

Received Feb 15, 2019: Accepted Apr 22, 2019
doi:10.4012/dmj.2019-045 JOI JST.JSTAGE/dmj/2019-045

Title: Clinical prospective evaluation of zirconia-based three-unit posterior fixed dental prostheses: Up-to ten-year results.

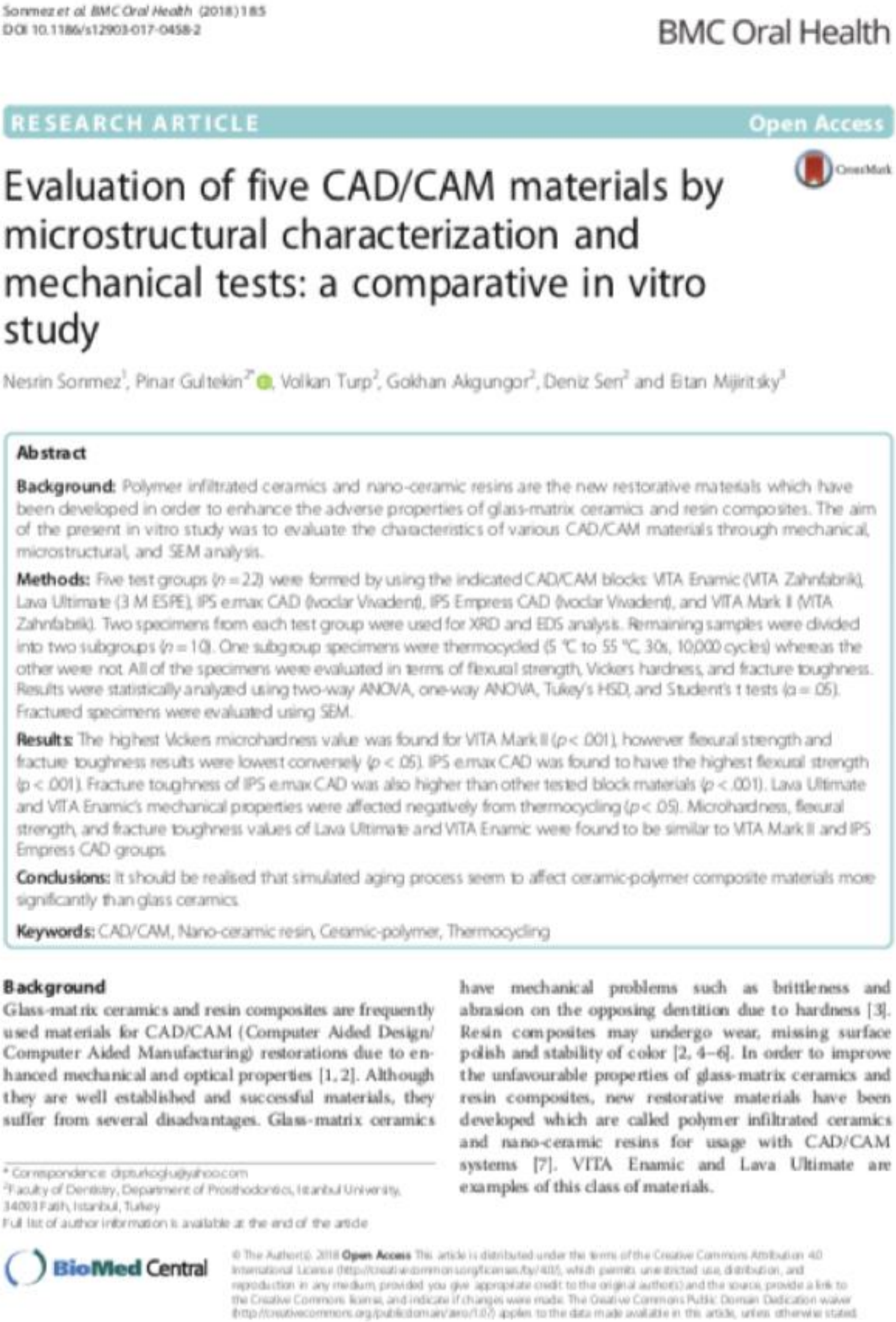
Author: Alexis Ioannidis Andreas Bindl

PII: S0300-5712(16)30014-8
DOI: http://dx.doi.org/doi:10.1016/j.jdent.2016.01.014
Reference: JJOD 2579

To appear in: *Journal of Dentistry*

Received date: 5-11-2015
Revised date: 8-1-2016
Accepted date: 30-1-2016

Please cite this article as: Ioannidis Alexis, Bindl Andreas.Clinical prospective evaluation of zirconia-based three-unit posterior fixed dental prostheses: Up-to ten-year results.*Journal of Dentistry* http://dx.doi.org/10.1016/j.jdent.2016.01.014



Sonmez et al. *BMC Oral Health* (2018) 18:5
DOI 10.1186/s12903-017-0458-2

BMC Oral Health

RESEARCH ARTICLE Open Access

Evaluation of five CAD/CAM materials by microstructural characterization and mechanical tests: a comparative in vitro study

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Abstract

Background: Polymer infiltrated ceramics and nano-ceramic resins are the new restorative materials which have been developed in order to enhance the adverse properties of glass-matrix ceramics and resin composites. The aim of the present in vitro study was to evaluate the characteristics of various CAD/CAM materials through mechanical, microstructural, and SEM analysis.

Methods: Five test groups ($n = 22$) were formed by using the indicated CAD/CAM blocks: VITA Enamic (VITA Zahnfabrik), Lava Ultimate (3 M ESPE), IPS e.max CAD (Ivoclar Vivadent), IPS Empress CAD (Ivoclar Vivadent), and VITA Mark II (VITA Zahnfabrik). Two specimens from each test group were used for XRD and EDS analysis. Remaining samples were divided into two subgroups ($n = 10$). One subgroup specimens were thermocycled (5 °C to 55 °C, 30s, 10,000 cycles) whereas the other were not. All of the specimens were evaluated in terms of flexural strength, Vickers hardness, and fracture toughness. Results were statistically analyzed using two-way ANOVA, one-way ANOVA, Tukey's HSD, and Student's t tests ($\alpha = .05$). Fractured specimens were evaluated using SEM.

Results: The highest Vickers microhardness value was found for VITA Mark II ($p < .001$), however flexural strength and fracture toughness results were lowest conversely ($p < .05$). IPS e.max CAD was found to have the highest flexural strength ($p < .001$). Fracture toughness of IPS e.max CAD was also higher than other tested block materials ($p < .001$). Lava Ultimate and VITA Enamic's mechanical properties were affected negatively from thermocycling ($p < .05$). Microhardness, flexural strength, and fracture toughness values of Lava Ultimate and VITA Enamic were found to be similar to VITA Mark II and IPS Empress CAD groups.

Conclusions: It should be realised that simulated aging process seem to affect ceramic-polymer composite materials more significantly than glass ceramics.

Keywords: CAD/CAM, Nano-ceramic resin, Ceramic-polymer, Thermocycling

Background

Glass-matrix ceramics and resin composites are frequently used materials for CAD/CAM (Computer Aided Design/Computer Aided Manufacturing) restorations due to enhanced mechanical and optical properties [1, 2]. Although they are well established and successful materials, they suffer from several disadvantages. Glass-matrix ceramics have mechanical problems such as brittleness and abrasion on the opposing dentition due to hardness [3]. Resin composites may undergo wear, missing surface polish and stability of color [2, 4–6]. In order to improve the unfavourable properties of glass-matrix ceramics and resin composites, new restorative materials have been developed which are called polymer infiltrated ceramics and nano-ceramic resins for usage with CAD/CAM systems [7]. VITA Enamic and Lava Ultimate are examples of this class of materials.

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Critical Reviews in Oral Biology & Medicine

Journal of Dental Research
1–9
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sagepub.com/journalsPermissions.nav
DOI: 10.1177/0022034516634286
jdr.sagepub.com

From Artisanal to CAD-CAM Blocks: State of the Art of Indirect Composites

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Abstract

Indirect composites have been undergoing an impressive evolution over the last few years. Specifically, recent developments in computer-aided design–computer-aided manufacturing (CAD-CAM) blocks have been associated with new polymerization modes, innovative microstructures, and different compositions. All these recent breakthroughs have introduced important gaps among the properties of the different materials. This critical state-of-the-art review analyzes the strengths and weaknesses of the different varieties of CAD-CAM composite materials, especially as compared with direct and artisanal indirect composites. Indeed, new polymerization modes used for CAD-CAM blocks—especially high temperature (HT) and, most of all, high temperature–high pressure (HT-HP)—are shown to significantly increase the degree of conversion in comparison with light-cured composites. Industrial processes also allow for the augmentation of the filler content and for the realization of more homogeneous structures with fewer flaws. In addition, due to their increased degree of conversion and their different monomer composition, some CAD-CAM blocks are more advantageous in terms of toxicity and monomer release. Finally, materials with a polymer-infiltrated ceramic network (PICN) microstructure exhibit higher flexural strength and a more favorable elasticity modulus than materials with a dispersed filler microstructure. Consequently, some high-performance composite CAD-CAM blocks—particularly experimental PICNs—can now rival glass-ceramics, such as lithium-disilicate glass-ceramics, for use as bonded partial restorations and crowns on natural teeth and implants. Being able to be manufactured in very low thicknesses, they offer the possibility of developing innovative minimally invasive treatment strategies, such as "no prep" treatment of worn dentition. Current issues are related to the study of bonding and wear properties of the different varieties of CAD-CAM composites. There is also a crucial need to conduct clinical studies. Last, manufacturers should provide more complete information regarding their product polymerization process, microstructure, and composition, which significantly influence CAD-CAM material properties.

Keywords: polymer-infiltrated ceramic network, high temperature–high pressure polymerization, mechanical properties, toxicity, degree of conversion, minimally invasive dentistry

Introduction

Nowadays, dental composites represent a wide and complex variety of materials with an increasing range of properties and indications. The latest developments of computer-aided design–computer-aided manufacturing (CAD-CAM) blocks are especially associated with new polymerization modes, innovative microstructures, and different compositions. All these changes have introduced important gaps among the different classes of indirect composites (ICs) in terms of mechanical properties, chemical stability, biological properties, bonding properties, and long-term performance probability, notably in comparison with ceramic materials (Coldea et al. 2013; Nguyen et al. 2014; Phan et al. 2014; Awada and Nathanson 2015; Swain et al. 2015). These recent and rapid breakthroughs are sometimes associated with confusion about the specific characteristics of emerging materials, which is augmented by incomplete or misleading information delivered by companies. Currently, some materials are listed either as ceramic-like or in composite materials, under a large variety of names, such as resin nanoceramics, hybrid ceramics, resin-matrix ceramics, double-network materials, ceramic-based interpenetrating-phase composites, or polymer-infiltrated ceramic network (PICN; Denry and Kelly 2014; Gracis et al. 2015). Consequently, the aim of this work is to critically review the global evolution of ICs to understand their respective properties and the contribution of new materials to treatment strategies improvement.

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A supplemental appendix to this article is published electronically only at http://jdr.sagepub.com/supplemental.

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Clinical Marginal and Internal Adaptation of Maxillary Anterior Single All-Ceramic Crowns and 2-year Randomized Controlled Clinical Trial

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Keywords
All-ceramic; marginal adaptation; internal adaptation; CAD/CAM; heat-pressed.

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Presented at the FDI 2013 Annual World Dental Conference, Istanbul, Turkey, 28–31 August 2013.

The authors deny any conflicts of interest.

Accepted April 22, 2014

doi: 10.1111/jopr.12217

Abstract

Purpose: The aims of this randomized-controlled clinical trial were to compare marginal and internal adaptation of all-ceramic crowns fabricated with CAD/CAM and heat-pressed (HP) techniques before luting and to evaluate the clinical outcomes at baseline and at 6, 12, and 24 months after luting.
Materials and Methods: Fifteen CAD/CAM (CC) and 15 HP all-ceramic crowns were placed in 15 patients. A silicone replica was obtained to measure marginal and internal adaptation of each all-ceramic crown before luting, and they were sectioned buccolingually and mesiodistally. Marginal and internal adaptations were measured using computerized light microscope at 40× magnification. Clinical evaluations took place at baseline (2 days after luting) and at 6, 12, and 24 months after luting. Replica scores were analyzed with Mann-Whitney U and Student's *t*-test ($\alpha = 0.05$). Survival rate of crowns was determined using Kaplan-Meier statistical analysis.
Results: The median marginal gap for the CC group was 132.2 μm and was 130.2 μm for the HP group. The mean internal adaptation for the CC group was 220.3 ± 51.3 μm and 210.5 ± 31 μm for the HP group. There were no statistically significant differences with respect to marginal opening (Mann-Whitney U test; $p = 0.95$) and internal adaptation (Student's *t*-test; $p = 0.535$) between the 2 groups. Based on modified Ryge criteria, 100% of the crowns were rated satisfactory during the 2-year period.
Conclusion: In this in vivo study, CAD/CAM and HP all-ceramic crowns exhibited similar marginal and internal adaptations. A 100% success rate was recorded for the 15 CAD/CAM and for the 15 HP all-ceramic crowns during the 2-year period.

All-ceramic crowns have become more popular as a result of increasing demand for esthetic corrections.[1,2] All-ceramic crowns can be fabricated through computer aided design/computer aided manufacturing (CAD/CAM) or can be heat-pressed (HP).[1,3] The HP technique is based on the lost-wax principle. Prefabricated ceramic ingots are heated and then pressed into the lost-wax form of a crown coping. Dental CAD/CAM systems such as CEREC (Sirona Dental, Charlotte, NC, USA) use a scanning and milling process to fabricate all-ceramic copings from prefabricated ceramic blocks.[4-6] Today it is accepted that all-ceramic crowns should be luted using adhesive luting techniques.[7,8] Hydrofluoric acid etching followed by the application of a silane agent is a common and clinically well-proven procedure for silicate ceramics.[9,10]

In case of insufficient adaptation at the crown margin, cement solubility, and plaque retention may occur, which is harmful for both tooth structure and periodontal tissues.[11-15] Besides adaptation of the crown at the margin, luting space dimension is also an important aspect.[16,17] The luting space needs to be uniform to facilitate placement without compromising retention and resistance. This is particularly important for all-ceramic materials, which are more fragile than cast alloys.[16,18] Clinicians may be subjected to certain intraoral conditions that cannot be reproduced in laboratory settings.[19] These conditions include multiple intermittent cyclic forces during chewing, grinding, and clenching, constant exposure to a moist, bacteria-rich environment, consumption of too hot or too cold liquids and acids, and traumatic or inadequate tooth brushing. In addition, specimens used for testing dental ceramics in the laboratory sometimes differ significantly in both size and structure from the restorations they represent.[20] Therefore, in vivo evaluation has been the basis for establishing criteria for clinically successful and acceptable crowns.[21-29]

The aims of this randomized-controlled single-blinded (evaluator) clinical trial were to compare marginal and internal adaptation of two all-ceramic crowns fabricated with CAD/CAM

Australian Dental Journal
The official journal of the Australian Dental Association

Australian Dental Journal 2020; 65: 150–157

doi: 10.1111/adj.12748

A comparison of the marginal gaps of lithium disilicate crowns fabricated by two different intraoral scanners

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ABSTRACT

Background: The purpose of this study was to assess marginal gaps of CAD/CAM lithium disilicate crowns constructed using two different intraoral scanners of different generations.

Methods: Twenty four Columbia model lower left molars were prepared for lithium disilicate crowns in a simulated environment by undergraduate students. The crown preparations were scanned by E4D and Trios 3 intraoral scanners and CAD/CAM lithium disilicate crowns designed and manufactured. The crowns were seated onto the original crown preparations and three vertical marginal gap measurements taken at four locations (mid-buccal, mid-lingual, mid-mesial and mid-distal) using a stereomicroscope. The mean marginal gap (MMG) was calculated for each crown and each individual tooth surface.

Results: The MMG was not statistically significantly different for the Trios 3 and E4D scanners ($P = 0.111$). There was no statistically significant effect of measurement location on the tooth on the marginal gap ($P = 0.1134$).

Conclusions: There was no difference in the MMGs of CAD/CAM lithium disilicate crowns constructed using two different intraoral scanners of different generations. Within the limitations of this study, the advances in scanning technology have produced small and insignificant improvements in the accuracy of crown margins.

Keywords: Cement space, ceramic, crown, marginal gap, scanner.

Abbreviations and acronyms: AMD = absolute marginal discrepancy; CAD/CAM = computer-aided design/computer-aided manufacture; CBCT = cone beam computed tomography; CLSM = confocal laser scanning microscopy; IOS = intraoral scanners; MMG = mean marginal gap; OCT = optical coherence tomography; PVS = polyvinylsiloxane; STL = standard triangulation language.

(Accepted for publication 6 February 2020.)

INTRODUCTION

Since the first intraoral scanner (IOS) was introduced in 1971,[1] digital dentistry has seen an increase in capability and application of software, as well as improvements to hardware. While it was initially designed for the fabrication of inlays, onlays, copings and crowns, the scope of intraoral scanners and digital dentistry has expanded to include applications in orthodontics, implantology, and oral and maxillofacial surgery.[2,3] The time efficiency, convenience and comfort offered by digital impressions have been shown to contribute to the patient's preference between digital and conventional workflows.[4–7]

Several studies have investigated the difference in accuracy and precision between intraoral scanning systems by utilizing methods such as digital three-dimensional surface analysis,[8–10] or assessing the marginal and internal fit of crowns fabricated from different systems.[11–13] The use of different optical systems and scanning strategies has been shown to influence the scanning accuracy.[14] Additionally, the software design and method of data processing and image triangulation can influence the resolution and surface topography of the final digital impression produced.[15,16]

With the increasing demand for aesthetics, all-ceramic restorations have become a popular alternative to conventional metal-ceramic restorations. Lithium disilicate was first introduced in 1988 as lithium disilicate ingots for use in the conventional lost-wax pressed ceramic technique. The material has since been developed to be used in digital workflows as a machinable monolithic ceramic block.[17] With its high flexural strength and fracture toughness,[17] CAD/CAM lithium disilicate provides another aesthetic material option for the clinician in the digital workflow, making in-office milling and same-day restorations a possibility. While some studies find the conventional pressed technique provides more accurate

Australian Dental Journal
The official journal of the Australian Dental Association

Australian Dental Journal 2019; 64: 167–174

doi: 10.1111/adj.12688

The influence of different cement spaces on the marginal gap of CAD/CAM all-ceramic crowns

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ABSTRACT

Background: The purpose of this study was to measure the marginal gaps of CAD/CAM all-ceramic crowns constructed using different cement spaces on crown preparations created by undergraduate students.
Methods: Twenty-four Columbia model lower left first molars with assessed tapers and reduction volumes (RV) were recruited to receive complete coverage E.max crowns. Three E.max crowns were digitally designed and milled for each crown preparation using three different cement spaces: 50 μm (CS-50), 100 μm (CS-100), 200 μm (CS-200). Each crown was seated onto its original crown preparation and three vertical marginal gap measurements were taken at four locations (mid-buccal, mid-lingual, mid-mesial, mid-distal) using a stereomicroscope. The mean marginal gap (MMG) was calculated for each crown and each individual tooth surface.
Results: The MMG was statistically significantly different for each of the three cement spaces (126 μm for CS-50, 89 μm for CS-100, and 75 μm for CS-200) ($P < 0.0001$). A taper of between 20 and 30° produced the smallest MMG. Insufficient RV caused significantly larger MMGs. The buccal margin had significantly smaller MMGs than all other measured surfaces.
Conclusions: The most accurate margins of digitally designed all-ceramic crowns constructed on simulation teeth prepared by undergraduate students were observed when using a 200 μm cement space.

Keywords: Marginal gap, Cement space, Ceramic, Crown, E4D.

Abbreviations and acronyms: BL = bucco-lingual; CAD/CAM = computer-aided design/computer-aided manufacturing; CS = cement space; MD = mesio-distal; MMGITS = mean marginal gaps for individual tooth surfaces; MMG = mean marginal gap; MPa = megapascals; RV = reduction volume.

(Accepted for publication 12 March 2019.)

INTRODUCTION

All-ceramic crowns have gained recent popularity amongst dentists and patients due to their excellent aesthetics, ease of fabrication and biocompatibility. Utilising computer-aided design and computer-aided manufacturing (CAD/CAM) technology, all-ceramic crowns offer construction benefits over more traditional porcelain bonded to metal crowns including fewer laboratory stages, simplified laboratory techniques, greater repeatability and reduced laboratory fees.[1]

Ceramics are brittle and exhibit high compressive strength but low flexural strength. It is important to provide appropriate crown preparation dimensions to minimse internal stresses, for accurate marginal and internal fit, and to maximise long-term clinical success.[2–5] A popular ceramic on the market is IPS E.max, an aesthetic lithium disilicate material with a flexural strength of 360 MPa, high fracture toughness and a wide range of proposed clinical uses.[6]

The E4D Dentist (E4D Dentist, D4D Technologies, Richardson, TX, USA) is an in-office laser scanning CAD/CAM system that captures multiple individual images to form a three-dimensional virtual model. A ceramic restoration might be created via a user-friendly and streamlined step-by-step design process and the final design sent to the milling machine to complete the fabrication process, potentially enabling single visit restorations. One parameter that requires defining during the design process is the cement space.

A large range of cement spaces have been recommended in the past but studies investigating the influence of different cement spaces on the marginal gap have been carried out on ideal preparations with minimal degrees of taper with generally small cement spaces which might not reflect real-life clinical situations where less experienced operators and students

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CLINICAL RESEARCH

Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic posterior fixed partial dentures. Part II: Time efficiency of CAD-CAM versus conventional laboratory procedures

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Christoph H. F. Hämmerle, Dr med dent,[d] and Irena Sailer, Dr med dent[e]

ABSTRACT

Statement of problem. Clinical trials are needed to evaluate the digital and conventional fabrication technology for providing fixed partial dentures (FPDs).

Purpose. The purpose of the second part of this clinical study was to compare the laboratory production time for tooth-supported, 3-unit FPDs by means of computer-aided design and computer-aided manufacturing (CAD-CAM) systems and a conventional workflow. In addition, the quality of the 3-unit framework of each treatment group was evaluated clinically.

Material and methods. For each of 10 participants, a 3-unit FPD was fabricated. Zirconia was used as the framework material in the CAD-CAM systems and included Lava C.O.S. CAD software (3M) and centralized CAM (group L); CARES CAD software (Institut Straumann AG) and centralized CAM (group iT); and CEREC Connect CAD software (Dentsply Sirona) and centralized CAM (group C). The noble metal framework in the conventional workflow (group K) was fabricated by means of the traditional lost-wax technique. All frameworks were evaluated clinically before veneering. The time for the fabrication of the cast, the 3-unit framework, and the veneering process was recorded. In addition, chairside time during the clinical appointment for the evaluation of the framework was recorded. The paired Wilcoxon test together with appropriate Bonferroni correction was applied to detect differences among treatment groups (α=.05).

Results. The total effective working time (mean ±standard deviation) for the dental technician was 220 ±29 minutes in group L, 217 ±23 minutes in group iT, 262 ±22 minutes in group C, and 370 ±34 minutes in group K. The dental technician spent significantly more time in the conventional workflow than in the digital workflow, independent of the CAD-CAM systems used ($P<.001$).

Conclusions. Irrespective of the CAD-CAM system, the overall laboratory time for the dental technician was significantly less for a digital workflow than for the conventional workflow. (J Prosthet Dent 2018;■■-■)

As zirconia restorations cannot be made with conventional fabrication techniques, it was only in the 1990s that computer-aided design and computer-aided manufacturing (CAD-CAM) technology allowed the introduction of zirconia as a dental prosthetic material.[1] Zirconia has excellent mechanical properties and can therefore be successfully used as a dental framework material.[2,3]

Multiunit prostheses are generally fabricated in the dental laboratory. The start of the CAD-CAM process depends on the location of the scanner. Intraoral digital scanners allow dentists to make intraoral scans of the tooth preparations.[4] Subsequently, the data file is digitally transferred to the dental

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Supported by the Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Switzerland and by a research grant from Institut Straumann AG, Basel, Switzerland.

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Journal of the Mechanical Behavior of Biomedical Materials 103 (2020) 103579

Contents lists available at ScienceDirect

Journal of the Mechanical Behavior of Biomedical Materials

journal homepage: http://www.elsevier.com/locate/jmbbm

Three-body wear effect on different CAD/CAM ceramics staining durability

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ARTICLE INFO

Keywords:
Ceramics
ACTA wear machine
Wear facet
Wear depth and wear volume

ABSTRACT

Regardless the materials properties, the vast majority of ceramic restorations could require an individualization through the extrinsic staining to improve aesthetics. This study aimed to compare the staining wear durability of different monolithic ceramics. Specimens of high translucent zirconia (YZHT), zirconia reinforced lithium silicate (ZLS), hybrid ceramic (HC) and feldspathic ceramic (FLD) were divided in five groups according to each material staining technique. The ZLS ceramic was tested with stained prior (ZLS1) and after crystallization (ZLS2). All specimens were extrinsically characterized, i.e. stained, and crystallized or sintered in specific ovens, according to the manufacturer's recommendation. The specimens were submitted to three-body wear tests in ACTA wear machine, simulating the presence of food bolus and antagonist (pH 7, 15 N, 1 Hz). The wear rate of the stain surface was determined after 5 intervals of 200,000 cycles, using a profilometer. The ceramic surface before and after staining, and after wear were inspected by Scanning Electron Microscopy (SEM). The wear rates were analyzed using two-way ANOVA and post-hoc Tukey test. The wear rates of the staining were affected by ceramic and the number of cycles ($P < 0.001$). 100% of staining was removed after 200,000 cycles for HC, and after 600,000 cycles for YZHT and ZLS1. Staining of ZLS2 and FLD remained on ceramic surface even after 1,000,000 cycles. Furthermore, FLD showed a significant higher staining durability than ZLS2. SEM revealed different surface morphologies for each group with and without staining and after the wear test. Ceramics with fired staining showed higher durability compared to the polymerized one. The feldspar ceramic presented superior staining durability, followed by zirconia reinforced lithium silicate and high translucent zirconia. The conventional two steps staining technique showed improved durability for zirconia reinforced lithium silicate.

1. Introduction

Monolithic polycrystalline ceramics materials with excellent mechanical properties (Denry and Kelly, 2014), emerged in order to overcome failure by chipping in veneering ceramics, reduce clinical time and restorations costs (Stawarczyk et al., 2013; Sulaiman et al., 2015). In contrast, glass ceramics have excellent esthetic properties, but lower mechanical resistance in comparison to polycrystalline ceramics. Therefore, glass ceramics with crystals reinforcement or polymer infiltration were developed to improve their mechanical properties, but maintaining the esthetic properties (Bottino et al., 2015; Ramos et al., 2016; Sato et al., 2016; Dal Piva et al., 2018a,b).

Regardless the materials esthetic properties, some restorations require shade characterization or staining due to intrinsic characteristics of the ceramic material, like opacity, or due to individualization according to the patient esthetic needs. This extrinsic esthetic characterization can be performed using specific techniques according to the material composition. The most common technique for zirconia and glass ceramics involves the staining application on the external ceramic surfaces and two separate cycles of firing e.g staining and glaze layer. It is also possible to stain some ceramics prior to the crystalizing process (Sulaiman et al., 2015; Rinke et al., 2015; Garza et al., 2016, Willard and Chu, 2018), such as zirconia reinforced lithium silicate based materials (Vita Suprinity, Vita Zhanfabrik). However, the durability of the staining

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https://doi.org/10.1016/j.jmbbm.2019.103579
Received 27 August 2019; Received in revised form 28 November 2019; Accepted 2 December 2019

ARTICLE IN PRESS

THE JOURNAL OF PROSTHETIC DENTISTRY

DENTAL TECHNIQUE

A fully digital approach to fabricating a CAD-CAM ceramic crown to fit an existing removable partial denture

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ABSTRACT

The use of a fully digital approach to fabricate an anatomic contour crown to fit an existing removable prosthesis allows the dentist and the dental laboratory technician to work efficiently in a digital environment. This report presents a series of patient treatments involving the fabrication of an anatomic contour monolithic zirconia crown to retrofit an existing removable partial denture. A complete digital workflow comprises an intraoral digital scan and computer-aided design and computer-aided manufacturing (CAD-CAM) technology. (J Prosthet Dent 2018;■:■-■)

Replacing a crown on a tooth serving as an abutment for a removable partial denture (RPD) is considered one of the most difficult restorative procedures.[1] Various techniques have been reported, generally described as either direct or indirect.[2-5] The direct technique is where the outline of the restoration is fabricated intraorally as opposed to the indirect technique where all information is transferred to a gypsum cast, and the contour and design of the restoration are completed in the dental laboratory.[6,7]

The main advantage of the direct technique is that the patients can wear a functional RPD during the laboratory phase. However, increased clinical time is required to complete the intraoral waxing procedure, and inaccuracies could be incorporated because of the difficulty in manipulating the crown pattern in the oral environment. Conversely, the indirect technique permits the laboratory technician to work on the contour of the restoration with the existing RPD available. In this situation, the patient is deprived of the RPD, a typically unacceptable situation if an anterior tooth is replaced by the RPD. The disadvantages of this technique include reliance on the laboratory technician's experience, the shrinkage of the acrylic resin, and dimensional changes in the wax pattern that can lead to imprecisions in the contour of the definitive crown.[3,7]

The technique, direct or indirect, should be accurate and reasonably straightforward. The use of computer-aided design and computer-aided manufacturing (CAD-CAM) technology has become popular in fixed and removable prosthodontics, and its adoption has been associated with innovative, expedient, and precise methods of performing dental procedures. Different techniques have been described in which CAD-CAM technology is used to facilitate the fabrication of a surveyed crown, each with its own particularities and

Figure 1. Maxillary removable partial denture with metal-ceramic crowns on abutment teeth.

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THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL SCIENCE

Clinical performance of two different CAD/CAM-fabricated ceramic crowns: 2-Year results

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ABSTRACT

Statement of problem. Recently, technical problems, especially chipping, have been reported for ceramic restorations; as a result, ceramic crowns produced entirely by computer-aided design and computer-aided manufacture (CAD/CAM) have become popular because the incidence of chipping is less.

Purpose. The purpose of this study was to report on 2-year results for 2 different types of CAD/CAM ceramic crowns placed in adult patients in a dental practice.

Material and methods. Sixty participants who required a crown for a first or second molar were randomly assigned to 1 of 2 groups. Crowns in the veneered zirconia (VZ) group were made of zirconia frameworks veneered with CAD/CAM-produced lithium disilicate ceramic; the other group's crowns were made of monolithic lithium disilicate (MLD) ceramic. Each crown was reviewed after 2 weeks, 1 year, and 2 years by using modified the US Public Health Service (USPHS) criteria. Statistical analysis was performed by using the log-rank test, nonparametric tests, and Kaplan-Meier survival analysis.

Results. All 60 participants were recalled after 1 and 2 years. In the VZ group, 2 endodontic complications occurred, and deterioration of periodontal health was observed for 3 participants. In the MLD group, 2 endodontic complications occurred within 2 years. In both of the groups, no caries or marginal discoloration was observed. No technical complications, for example, cracks, chipping, or fractures, were detected after 2 years. The shape and appearance of all crowns were assessed positively by the examining dentist. The log-rank test showed no significant differences in respect to technical or biologic complications (P=.324).

Conclusion. For both types of single-crown restoration, no technical failures occurred. The number of biological complications did not differ significantly between the types of crowns. (J Prosthet Dent 2015;■:■-■)

Ceramic crowns have been used for many years with good results.[1-4] A variety of different materials and techniques are available for the production of ceramic restorations.[5] The decision about which ceramic material and/or method to use should be made for individual patients,[6] because no ceramic system is ideal for all clinical situations, and clinical results are affected by numerous factors.[7-9] Masticatory forces are greater in the molar region, and more clinical complications occur there than among anterior teeth.[1,2,10] Failure of the ceramic veneer is the most common damage; fracture of the core material is infrequent.[2,3,5]

Although several optimization strategies, including framework design and modified firing procedures, have already been developed to reduce chipping, ceramic crowns veneered with traditional techniques still seem susceptible.[11] Therefore, methods that eliminate a hand-crafted veneer or even make veneer entirely unnecessary have recently been introduced. These developments have been made possible not only by the use of computer-aided design and computer-aided manufacture (CAD/CAM)[12-16] but also by the use of veneer made, with CAD/CAM support, from feldspathic ceramic or lithium disilicate ceramic, which is then attached to the framework.[17] Alternatively, monolithic restorations can be made of lithium disilicate or zirconia ceramic; this technique completely eliminates the use of veneer. Another advantage of lithium disilicate ceramic is that processing[18-22] and clinical aspects[23-27] of this material have been well researched.

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Critical Review
Dental Materials/Dentistry

Dental ceramics: a review of new materials and processing methods

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Abstract: The evolution of computerized systems for the production of dental restorations associated to the development of novel microstructures for ceramic materials has caused an important change in the clinical workflow for dentists and technicians, as well as in the treatment options offered to patients. New microstructures have also been developed by the industry in order to offer ceramic and composite materials with optimized properties, *i.e.*, good mechanical properties, appropriate wear behavior and acceptable aesthetic characteristics. The objective of this literature review is to discuss the main advantages and disadvantages of the new ceramic systems and processing methods. The manuscript is divided in five parts: I) monolithic zirconia restorations; II) multilayered dental prostheses; III) new glass-ceramics; IV) polymer infiltrated ceramics; and V) novel processing technologies. Dental ceramics and processing technologies have evolved significantly in the past ten years, with most of the evolution being related to new microstructures and CAD-CAM methods. In addition, a trend towards the use of monolithic restorations has changed the way clinicians produce all-ceramic dental prostheses, since the more aesthetic multilayered restorations unfortunately are more prone to chipping or delamination. Composite materials processed via CAD-CAM have become an interesting option, as they have intermediate properties between ceramics and polymers and are more easily milled and polished.

Keywords: Ceramics; Dental Materials; Dental Porcelain; Computer-Aided Design; Composite Resins.

Declaration of Interest: The authors certify that they have no commercial or associative interest that represents a conflict of interest in connection with the manuscript.

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https://doi.org/10.1590/1807-3107BOR-2017.vol31.0058

Submitted: May 15, 2017
Accepted for publication: May 22, 20117
Last revision: May 25, 2017

Introduction

The evolution of computerized systems for the production of dental restorations associated to the development of novel microstructures for ceramic materials has caused an important change in the clinical workflow for dentists and technicians, as well as in the treatment options offered to patients. One of the most important changes in this scenario was the introduction of monolithic restorations produced from high-strength ceramics, like zirconia. This concept *per se* is not new, since ceramic materials have been used for a relatively long time for the production of monolithic restorations, but it was only when zirconia started to be used to produce full-contour crowns that dentists and technicians became more confident to indicate a ceramic material for crowns and bridges in the posterior region.

Emre Tezulas, Coskun Yildiz, Ceren Kucuk, Erkut Kahramanoglu

Current status of zirconia-based all-ceramic restorations fabricated by the digital veneering technique: a comprehensive review

Abstract

Objectives: Delamination and chipping are major complications of veneering material on zirconia-based all-ceramic restorations. The digital veneering technique was introduced to overcome these complications as both zirconia frameworks and veneering ceramic are fabricated by computer-aided design/computer-aided manufacturing (CAD/CAM). The aim of this review is to report all articles that evaluate zirconia-based all-ceramic restorations fabricated by the digital veneering technique. Three different digital veneering techniques were detected: the Lava DVS Digital Veneering System (3M ESPE), the Rapid Layer Technology (Vita Zahnfabrik), and the CAD-on technique (Ivoclar Vivadent). There are also some modifications of these techniques in the literature.

Materials and methods: For this review, a comprehensive literature search was conducted. Detected studies are reported according to fracture resistance, flexural strength, wear performance, shear bond strength, microtensile bond strength, mechanical performance of restorations on implant abutments, marginal fit, color reproducibility, and clinical success for all types of digital veneering techniques.

Results and conclusions: Anatomical framework design and digital veneering using lithium disilicate and fusion porcelain might decrease the risk of chipping and delamination of veneering ceramic on zirconia-supported all-ceramic restorations. However, this result is mainly supported by *in vitro* studies. More clinical studies with a large sample size, longer follow-up period, and different fixed dental prosthesis designs are needed.

Keywords: *digital veneering, zirconia, CAD-on, rapid layer, sintering technique*

Introduction

Zirconia dental restorations are being increasingly used due to their improved esthetics, biocompatibility, and mechanical properties.[1-3] As zirconia has high mechanical strength and a translucency similar to that of dentin, it is used as a framework that is veneered with esthetic ceramics.[4,5] Zirconia-based all-ceramic fixed dental prostheses (FDPs) achieve esthetics in the posterior region and are used for the fabrication of esthetic restorations that are longer than three units in the anterior region.

There are several techniques for producing zirconia-based all-ceramic restorations; the layering and the pressing techniques being the traditional ones. For the layering technique, the ceramic powder is mixed with liquid and applied to the zirconia core material, which is larger than its final dimensions to compensate for volumetric shrinkage of the ceramic.[6,7] The pressing technique involves waxing up the restorations to the desired tooth anatomy directly onto the zirconia core. The wax patterns are invested and burned out, and the pressable ceramic is then heat-pressed into the veneer space in the investment ring.[8]

Delamination (adhesive failure) and chipping (cohesive failure) are major complications of veneering material in zirconia-based all-ceramic restorations.[9,10] The layering technique has the disadvantage of micropore formation during lamination. Frequent failures of veneering porcelain are reported in the literature for the layering and pressing techniques. These are caused by different factors,[11,12] including discrepancy in the thermal expansion coefficient between the veneering ceramic and the zirconia, the design and connector size (< 9 mm^2) of the framework, and the lower flexural strength of the veneering ceramic (120 MPa).[13]

A new veneering method, the digital veneering technique, was introduced for producing zirconia-based all-ceramic restorations.[14] There are three different techniques for the digital veneering of zirconia frameworks: the Lava DVS Digital Veneering System (3M ESPE), the Rapid Layer Technology (Vita Zahnfabrik), and the CAD-on technique (Ivoclar Vivadent).[15-18] All three techniques use computer-aided design (CAD) of a full-contour restoration that is divided into two files (file splitting); one file is responsible for the computer-aided manufacture (CAM) fabrication of the zirconia framework, and the other for the CAM fabrication of the corresponding veneering material. The materials and their minimal

Combining Esthetic Layering and Lithium Disilicate Sintering Technique on Zirconia Frameworks: A Veneering Option to Prevent Ceramic Chipping

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Major and minor chipping of veneering porcelain are two of the most frequent complications in all-ceramic restorations with zirconia frameworks. In cases of major chipping, replacement of the affected restoration may be necessary. High-strength lithium disilicate ceramic offers new options to serve as veneering material in a sintering technique or as repair material for chipping in combination with the adhesive technique. The purpose of three case presentations here was to describe the use of lithium disilicate ceramic on zirconia frameworks for reliable and esthetic veneering in the posterior region and to repair extended chipping in conventional veneering materials.
Int J Periodontics Restorative Dent 2017;37:561–569. doi: 10.11607/prd.3043

Several types of ceramics are commercially available in dental practice and laboratories with a wide spectrum of indications, depending on the type of restoration.[1–6] Ceramic frameworks can be fabricated from materials such as lithium disilicate (LS$_2$) or zirconia (Zr).[7–11] LS$_2$ presents good mechanical properties including flexural strength (350 MPa machine milled to 400 MPa pressed), excellent esthetic results, and the possibility of imitating the natural tooth structure.[7] However, its main indication remains use in single-tooth restorations because the mechanical properties of LS$_2$ are inferior to those of Zr-based ceramics (flexural strength of 900 to 1200 MPa and fracture toughness of 9 to 10 MPa-m$^{1/2}$).[12] Zr is the predominantly used all-ceramic framework material in the posterior region because of its versatility.[9]

Zr stabilized with 3 mol% yttrium (3Y-TZP) offers superior mechanical properties and biocompatibility.[10] However, conventional Zr presents some limitations, such as long-term hydrothermal degradation and an opaque white appearance.[8,10] In general, a veneering of the Zr framework with silica-based ceramics is considered advantageous.[10] Various techniques are described to perform this layering, including the powder layer technique,[11] the overpressing technique,[11] and the sintering

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DENTAL MATERIALS XXX (2015) XXX–XXX

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Flexural strength and reliability of monolithic and trilayer ceramic structures obtained by the CAD-on technique

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ARTICLE INFO

Article history:
Received 6 February 2015
Received in revised form
21 July 2015
Accepted 21 September 2015
Available online xxx

Keywords:
Dental ceramics
Flexural strength
Monolithic and trilayer structures
Fractography

ABSTRACT

Objective. To evaluate the flexural strength, Weibull modulus, fracture toughness, and failure behavior of ceramic structures obtained by the CAD-on technique, testing the null hypothesis that trilayer structures show similar properties to monolithic structures.

Methods. Bar-shaped (1.8 mm × 4 mm × 16 mm) monolithic specimens of zirconia (IPS e.max ZirCAD – Ivoclar Vivadent) and trilayer specimens of zirconia/fusion ceramic/lithium dissilicate (IPS e.max ZirCAD/IPS e.max CAD Crystall./Connect/IPS e.max CAD, Ivoclar Vivadent) were fabricated ($n = 30$). Specimens were tested in flexure in 37 °C deionized water using a universal testing machine at a crosshead speed of 0.5 mm/min. Failure loads were recorded, and the flexural strength values were calculated. Fractography principles were used to examine the fracture surfaces under optical and scanning electron microscopy. Data were statistically analyzed using Student's *t*-test and Weibull statistics ($\alpha = 0.05$).

Results. Monolithic and trilayer specimens showed similar mean flexural strengths, characteristic strengths, and Weibull moduli. Trilayer structures showed greater mean critical flaw and fracture toughness values than monolithic specimens ($p < 0.001$). Most critical flaws in the trilayer groups were located on the Y-TZP surface subjected to tension and propagated catastrophically. Trilayer structures showed no flaw deflection at the interface.

Significance. Considering the CAD-on technique, the trilayer structures showed greater fracture toughness than the monolithic zirconia specimens.

1. Introduction

The development of (poly)crystalline dental ceramics, particularly yttrium-oxide tetragonal partially stabilized zirconia (Y-TZP), and the introduction of CAD/CAM (computer-aided design/computer-aided machining) technology have increased the use of metal free restorations in dentistry. CAD/CAM systems rely primarily on three steps: scanning the tooth preparation, data processing and computer designing of

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http://dx.doi.org/10.1016/j.dental.2015.09.013
0109-5641/© 2015 Academy of Dental Materials. Published by Elsevier Ltd. All rights reserved.

Please cite this article in press as: Basso GR, et al. Flexural strength and reliability of monolithic and trilayer ceramic structures obtained by the CAD-on technique. Dent Mater (2015), http://dx.doi.org/10.1016/j.dental.2015.09.013

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Fracture and Fatigue Resistance of Cemented versus Fused CAD-on Veneers over Customized Zirconia Implant Abutments

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Keywords
CAD-on veneers; fractography; fracture mechanics; fatigue.

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This study was supported by Science and Technology Development Fund (STDF) grant number 489.

The authors deny any conflicts of interest.

Accepted June 3, 2014

doi: 10.1111/jopr.12253

Abstract

Purpose: To evaluate the fracture mechanics of cemented versus fused CAD-on veneers on customized zirconia implant abutments.
Materials and Methods: Forty-five identical customized CAD/CAM zirconia implant abutments (0.5 mm thick) were prepared and seated on short titanium implant abutments (Ti base). A second scan was made to fabricate 45 CAD-on veneers (IPS Empress CAD, A2). Fifteen CAD-on veneers were cemented on the zirconia abutments (Panavia F2.0). Another 15 were fused to the zirconia abutments using low-fusing glass, while manually layered veneers served as control (n = 15). The restorations were subjected to artificial aging (3.2 million cycles between 5 and 10 kg in a water bath at 37°C) before being axially loaded to failure. Fractured specimens were examined using scanning electron microscopy to detect fracture origin, location, and size of critical crack. Stress at failure was calculated using fractography principles (alpha = 0.05).
Results: Cemented CAD-on restorations demonstrated significantly higher ($F = 72$, $p < 0.001$) fracture load compared to fused CAD-on and manually layered restorations. Fractographic analysis of fractured specimens indicated that cemented CAD-on veneers failed due to radial cracks originating from the veneer/resin interface. Branching of the critical crack was observed in the bulk of the veneer. Fused CAD-on veneers demonstrated cohesive fracture originating at the thickest part of the veneer ceramic, while manually layered veneers failed due to interfacial fracture at the zirconia/veneer interface.
Conclusions: Within the limitations of this study, cemented CAD-on veneers on customized zirconia implant abutments demonstrated higher fracture than fused and manually layered veneers.

Computerized dentistry is gaining attention, allowing a quick and thorough diagnosis of clinical problems, offering multiple solutions for the patient, and allowing fabrication of accurate and complex restorations with nothing more than a few keyboard clicks. Early computer-assisted design/computer-assisted manufacturing systems (CAD/CAM) focused on fabrication of customized all-ceramic frameworks and copings that were later veneered using different techniques.[1] With improvements in software and advances in milling potential, CAD/CAM technology was deployed to fabricate implant abutments,[2] temporary restorations, metallic frameworks, esthetic veneers, and even larger objects, such as surgical guides and removable denture bases.[3]

Meanwhile, the fabrication of CAD/CAM zirconia or metallic frameworks became a totally digital process. Application of the veneer ceramic using either manual layering or press-on veneers requires an investment of much time and effort from the dental ceramist and remains liable to human errors, such as introduction of structural defects in the veneer material, occlusal misfits, or shade mismatch, making the final esthetic outcome difficult to predict. Additionally, manually layered veneers are associated with creation of internal stresses at the framework/veneer interface related to mismatch in thermal expansion coefficient and to cooling stresses. These internal stresses were recently deemed a probable cause for chipping failure of the veneer ceramic.[4] Additional factors such as

Effect of Veneering Techniques on Shear and Microtensile Bond Strengths of Zirconia-Based All-Ceramic Systems

Tuba Yilmaz Savas[a] / Filiz Aykent[b]

Purpose: To evaluate shear (SBS) and microtensile (μTBS) bond strengths of zirconia cores veneered using different fabrication techniques.

Materials and Methods: Seventy-five IPS e.max ZirCAD plates were fabricated and divided into three groups according to the following veneering techniques: layering, pressing, and CAD-on. The specimens of the layering group were veneered with IPS e.max Ceram, and the specimens of the pressing group were veneered with IPS e.max ZirPress. Veneering ceramics in the CAD-on group were milled from IPS e.max CAD, fused with the core by using a glass-fusion ceramic, and then crystallized. Bond strength tests were performed using a universal testing machine at a crosshead speed of 0.5 mm/min for the SBS test and 1 mm/min for the μTBS test. Mean SBS and μTBS (MPa) were analyzed with one-way ANOVA and Tukey's HSD test ($p < 0.05$).

Results: Significant differences in SBS were observed between the groups ($p < 0.05$). The mean SBS for the CAD-on group was significantly higher (31.89 ± 5.83 MPa) than those of the layering (14.27 ± 4.45 MPa) and pressing (12.23 ± 3.04 MPa) groups. However, the mean μTBS of the CAD-on (30.41 ± 8.64 MPa), layering (21.71 ± 3.40 MPa) and pressing (20.74 ± 6.36 MPa) groups were not statistically significant ($p > 0.05$).

Conclusion: The CAD-on technique showed the highest shear bond strengths of the tested groups, and most of the specimens failed cohesively instead of failing at the adhesive interface.

Keywords: zirconia, veneering techniques, CAD-on, all-ceramics, bond strength.

J Adhes Dent 2017; 19: 507–515.
doi: 10.3290/j.jad.a39595

Submitted for publication: 19.10.15; accepted for publication: 20.11.17

The results of the shear bond strength section of this study were previously presented at the IADR/PER Congress, Dubrovnik, Croatia, September 9–13, 2014, and the results of the microtensile bond strength section were presented at The European Prosthodontic Association Congress, İstanbul, Turkey, September 25–27, 2014.

With the introduction of high strength yttria-partially stabilized tetragonal zirconia (Y-TZP) as a core material, zirconia-based restorations have become a suitable alternative to traditional metal-ceramic restorations.[19,41] Its good biocompatibility, white color, transformation toughening, high strength, and stability have made zirconia the preferred core material for all-ceramic restorations.[20] Although they are white and relatively translucent,[46] zirconia cores are veneered with a ceramic material to achieve an esthetically pleasing and natural appearance.[40]

Various veneering materials and techniques are available for the zirconia core material. The layering technique has been the principal method of applying veneering ceramics to the core material.[23] In this technique, the ceramic powder is mixed with its liquid and applied to the zirconia core material, which is larger than its final dimensions to compensate for volumetric shrinkage of the ceramic.[23,25] In contrast, the pressing technique involves waxing up the restorations to the desired tooth anatomy directly onto the zirconia core. The wax patterns are invested and burned out, and the pressable ceramic is then heat-pressed into the veneer space in the investment ring.[23] Besides these well-known veneering techniques, a new technique has been introduced that involves CAD/CAM of both the zirconia core and the veneer ceramic.[12] Because the ceramic blocks are produced industrially, this technique results in almost flawless components.[38] In the new technique, the veneer is milled from a lithium disilicate ceramic and adapted to a milled-sintered zirconia framework. A fusion ceramic is

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JPOR-302; No. of Pages 8
ARTICLE IN PRESS
JOURNAL OF PROSTHODONTIC RESEARCH XXX (2015) XXX–XXX

Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.elsevier.com/locate/jpor

Original article

Evaluation of shear bond strength of veneering ceramics and zirconia fabricated by the digital veneering method

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ARTICLE INFO

Article history:
Received 6 June 2015
Received in revised form
14 October 2015
Accepted 4 November 2015
Available online xxx

Keywords:
Zirconia core
Shear bond strength
Layering method
Heat pressing method
Digital veneering method

ABSTRACT

Purpose: The purpose of this study was to evaluate the shear bond strength (SBS) of veneering ceramic and zirconia fabricated by the digital veneering method.

Methods: A total of 50 specimens were fabricated, i.e., 10 specimens each for the metal-ceramic (control) group and the four zirconia groups. The zirconia groups comprised specimens fabricated by the digital veneering method, the heat pressing method, and hand layering method for two groups, respectively. Furthermore, the shear bond strength was measured with a universal testing machine (Model 3345, Instron, Canton, MA, USA) and statistically analyzed using one-way ANOVA set at a significance level of $P < 0.05$. The corresponding mode of failure was determined from Scanning Electron Microscope (FESEM JSM 6701F, Jeol Ltd., Japan) observations.

Results: One-way analysis of variance (ANOVA) revealed that the metal-ceramic group had the highest SBS (43.62 MPa), followed by the digital veneering method (28.29 MPa), the heat pressing method (18.89 MPa), and the layering method (18.65, 17.21 MPa). The samples fabricated by digital veneering had a significantly higher SBS than the other zirconia samples ($P < 0.05$). All of the samples exhibited mixed failure.

Conclusions: Veneering ceramic with a zirconia core that was fabricated via the digital veneering method is believed to be effective in clinical use since, its shear bond strength is significantly higher than that resulting from the conventional method.

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http://dx.doi.org/10.1016/j.jpor.2015.11.001

Please cite this article in press as: Sim J-Y, et al. Evaluation of shear bond strength of veneering ceramics and zirconia fabricated by the digital veneering method. J Prosthodont Res (2015), http://dx.doi.org/10.1016/j.jpor.2015.11.001

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Microtensile Bond Strength of Lithium Disilicate to Zirconia with the CAD-on Technique

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Keywords
All-ceramic; zirconia framework; CAD-on; Press-on; microtensile bond strength.

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Study presented as a poster at the American Association of Dental Research, Charlotte, NC on March 21, 2014.

The views expressed in this publication are those of the author and do not reflect the official policy of the Department of Defense, or other departments of the U.S. government. The authors do not have any financial interest in the companies whose materials are discussed in this publication.

Accepted June 8, 2014

doi: 10.1111/jopr.12246

Abstract

Purpose: Recently, a novel technique was introduced to combine lithium disilicate and zirconia into one restoration. The purpose of this study was to compare the microtensile bond strength of veneering ceramic to a zirconia core in two techniques: the e.max® CAD-on technique and the Press-on technique.
Materials and Methods: Group A was prepared by veneering sintered zirconia blocks (e.max® ZirCAD) with lithium disilicate blocks (e.max® CAD) using the CAD-on technique according to manufacturer's instructions. Group B was prepared by taking sintered e.max® ZirCAD blocks and veneering them with fluorapatite glass-ceramic (e.max® ZirPress) using the Press-on technique according to manufacturer's instructions. Each block was loaded in a dynamic cyclic loading machine. The blocks were then sectioned into 1×1 mm^2 beams ($n = 43$) using a precision saw, thermocycled, and loaded in tension until failure on a universal testing machine. A mean and standard deviation were determined per group. Data were analyzed using an unpaired t-test ($\alpha = 0.05$).
Results: The mean microtensile bond strengths were 44.0 ± 13.8 MPa for the CAD-on technique and 14.9 ± 8.8 MPa for the Press-on technique. Significant differences were found between the two groups ($p = 2.7E{-}19$).
Conclusions: The CAD-on technique (lithium disilicate/zirconia) resulted in greater microtensile bond strength than the Press-on technique (fluorapatite glass-ceramic/zirconia).

All-ceramic crowns and fixed dental prostheses (FDPs) are increasingly being used in clinical dentistry due to their optimal esthetics and ease of use. Regarding esthetics, all-ceramic crowns may be more esthetic than metal ceramic restorations, specifically due to their lack of metal substructure, which allows them to blend with natural teeth.[1] When CEREC®2 (Sirona Dental Systems, Charlotte, NC) was introduced in 1994, its capability of milling single unit crowns forever changed the landscape of all-ceramic restorations. Companies began to develop all-ceramic systems that not only attempted to meet esthetic demands, but also incorporated computer-aided design/computer-aided manufacturing (CAD/CAM) technology for chairside and laboratory uses. The benefits of milling indirect restorations using CAD/CAM include: ability to provide a definitive restoration for a patient the same day as tooth preparation, elimination of porosities inherent in hand-applied porcelain, elimination of casting errors by precise milling of frameworks, and compensation of volumetric shrinkage of core ceramics such as yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP).[2,3] Marginal adaptations as low as 9 to 15 μm have been achieved in milled restorations.[4] Also, it has been shown that in the right applications, these CAD/CAM all-ceramic restorations can have good durability, with the survival rate of all-ceramic FDPs with zirconia frameworks after 5 years being comparable to that of conventional metal ceramic FDPs at 8 years.[5,6]

Some of the success of all-ceramic crowns and FDPs can be attributed to the strength of the core materials. Today, Y-TZP is considered the core material of choice for all-ceramic posterior restorations, particularly FDPs, due to its superior flexural strength and fracture toughness compared to other

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Evaluation of Zirconium-Oxide-Based Ceramic Single-Unit Posterior Fixed Dental Prostheses (FDPs) Generated with Two CAD/CAM Systems Compared to Porcelain-Fused-to-Metal Single-Unit Posterior FDPs: A 5-Year Clinical Prospective Study

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Keywords
Metal-ceramic FDPs; zirconia–ceramic FDPs; success rate.

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Accepted August 13, 2011

doi: 10.1111/j.1532-849X.2011.00825.x

Abstract

Purpose: The purpose of this prospective clinical study was to determine the success rate of single-unit posterior fixed dental prostheses (FDPs) with zirconia copings generated with two CAD/CAM systems, compared to porcelain-fused-to-metal (PFM) single-unit posterior FDPs after 5 years of function.
Materials and Methods: From 2005 to 2006, 60 patients who needed a single-unit FDP on a first molar in the mandibular jaw (left or right) in a private office setting were included in this study. The 60 first mandibular molars were randomly divided into three groups (n = 20): in the control group (group C), 20 PFM FDPs were included. In the other two groups CAD/CAM technology was used for the fabrication of the zirconium-oxide copings: 20 single-unit posterior FDPs with zirconia copings were generated with the Procera system (group P, Nobel Biocare); 20 single-unit posterior FDPs with zirconia copings were generated with the Lava system (group L, 3M ESPE). For the ANOVA follow-up data, the clinical life table method was applied. The statistical analysis was performed using two nonparametric tests, the log-rank test for k-groups and the Fisher exact test.
Results: No statistically significant difference in the clinical outcome of zirconia–ceramic FDPs of both groups (P and L) evaluated together and metal–ceramic posterior single FDPs was found at 5 years of function; however, clinical data showed that technical problems, such as extended fracture of the veneering ceramic, tended to occur more frequently in the zirconia–ceramic FDP groups. The difference in the frequency of failure was statistically significant only in the comparison of groups C and P.
Conclusions: Even if no statistically significant difference in the clinical outcome of zirconia–ceramic FDPs of both groups (P and L) considered together and metal–ceramic posterior single FDPs was found at 5 years of function, clinical data showed that the two zirconia–ceramic FDP groups tended to have more frequent clinical problems: for this reason all the clinical and technical variables related to the use of zirconia–ceramic FDPs generated with CAD/CAM systems should be carefully considered prior to all treatment procedures.

Thanks to their growing awareness of esthetics and biocompatibility, patients increasingly request metal-free solutions.[1] Due to the successful use of all-ceramic crowns both in the anterior and posterior segments,[2-6] and with the introduction of advanced dental technology and high-strength ceramic materials, all-ceramic systems may become a viable treatment option. Such restorative all-ceramic systems must fulfill biomechanical requirements and provide longevity similar to metal-ceramic restorations[7-10] while providing enhanced esthetics.[11] Zirconia, which is a polycrystalline material without a glassy matrix and is partly stabilized by yttrium oxide (approximately 3 mol%), is a valid metal-free option. The use of zirconia has been

THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL RESEARCH

Randomized controlled clinical trial of digital and conventional workflows for the fabrication of zirconia-ceramic fixed partial dentures. Part III: Marginal and internal fit

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ABSTRACT

Statement of problem. Trials comparing the overall performances of digital and conventional workflows in restorative dentistry are lacking.

Purpose. The purpose of the third part of this clinical study was to test whether the fit of zirconia 3-unit frameworks for fixed partial dentures fabricated with fully digital workflows differed from that of metal frameworks fabricated with the conventional workflow.

Material and methods. In each of 10 participants, 4 fixed-partial-denture frameworks were fabricated for the same abutment teeth according to a randomly generated sequence. Digital workflows were applied for the fabrication of 3 zirconia frameworks with Lava, iTero, and Cerec infiniDent systems. The conventional workflow included a polyether impression, manual waxing, the lost-wax technique, and the casting of a metal framework. The discrepancies between the frameworks and the abutment teeth were registered using the replica technique with polyvinyl siloxane. The dimensions of the marginal discrepancy ($\text{Discrepancy}_{\text{marginal}}$) and the internal discrepancy in 4 different regions of interest ($\text{Discrepancy}_{\text{shoulder}}$, $\text{Discrepancy}_{\text{axial}}$, $\text{Discrepancy}_{\text{cusp}}$, and $\text{Discrepancy}_{\text{occlusal}}$) were assessed using a light microscope. Post hoc t tests with Bonferroni correction were applied to detect differences (α=.05).

Results. $\text{Discrepancy}_{\text{shoulder}}$ was 96.1 ±61.7 µm for the iTero, 106.9 ±96.0 µm for the Lava, 112.2 ±76.7 µm for the Cerec infiniDent, and 126.5 ±91.0 µm for the conventional workflow. The difference between the iTero and the conventional workflow was statistically significant (P=.029). $\text{Discrepancy}_{\text{occlusal}}$ was 153.5 ±66.8 µm for the iTero, 203.3 ±127.9 µm for the Lava, 179.7 ±63.1 µm for the Cerec infiniDent, and 148.8 ±66.8 µm for the conventional workflow. $\text{Discrepancy}_{\text{occlusal}}$ was significantly lower for the conventional workflow than for the Lava and the Cerec infindent workflows (P<.01). The iTero resulted in significantly lower values of $\text{Discrepancy}_{\text{occlusal}}$ than the Lava and the Cerec infiniDent workflows (P<.01).

Conclusions. In terms of framework fit in the region of the shoulder, digitally fabricated zirconia 3-unit frameworks presented similar or better fit than the conventionally fabricated metal frameworks. In the occlusal regions, the conventionally fabricated metal frameworks achieved a more favorable fit than the CAD-CAM zirconia frameworks. (J Prosthet Dent 2018;■:■-■)

The introduction of computer-aided design and computer-aided manufacturing (CAD-CAM) systems to dentistry has led to increased production efficiency and the introduction of new restorative materials, such as zirconia. Zirconia, because of its excellent mechanical characteristics, is a suitable alternative to the traditionally used metal frameworks for posterior fixed partial dentures (FPDs).[1-4]

An essential aspect of any restorative workflow is the marginal and internal fit of the resulting prosthesis. Poorly fitting margins are associated with a risk of caries through increased plaque accumulation and microleakage.[5,6] Internal fit can influence the mechanical stability of the ceramic restoration, and an increased internal discrepancy can

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Funding: This work was supported by the Clinic of Fixed and Removable Prosthodontics and Dental Material Science, Center of Dental Medicine, University of Zurich, Switzerland, and by a research grant from the Institut Straumann AG, Basel, Switzerland.

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