Jim Kessler, DDS

Course 8115: “Merging Today’s Restorative Options with Proven Principles: A Blueprint for Success”

Thursday, April 6

9 am - 12 pm
At the end of this presentation participants should be able to:

- understand the physical properties for all-ceramic materials with particular emphasis on what most frequently leads to failure
- determine the most appropriate restorative material and design for each clinical situation
- understand the preparation designs and laboratory communications necessary to maximize results with today’s ceramic materials
- confidently discuss the risks and benefits of contemporary restorative options with their patients and laboratory technicians.

Proven Principles

Good science happens slowly!

You & I do the clinical research for new materials!

Proven Principles

With bonding procedures, clinical (in-vivo) performance is routinely inferior to laboratory (in-vitro) results

With ceramic materials, the clinical (in-vivo) performance is routinely inferior to laboratory (in-vitro) results

Goals for Our Time Together

K Understand the physical properties of the various all-ceramic materials with particular emphasis on what frequently leads to failure
K Enhance your ability to confidently discuss the risks and benefits of contemporary restorative options with patients and laboratory technicians

Wear resistance equivalent to or lower than enamel
No fatigue with time and function
Fracture-proof in dimensions of 1 mm or less
Conservation of tooth structure
Maximum Esthetics
Economics/Efficiency

Metal-free restorations
Gold Resin
Gold
Gold

Properties of the ideal C & B material

Predictably Bondable-Conservative preparations
Etch-able Ceramics
All-Ceramic Restorations

Result=Delayed Failure!

Ceramic materials do not fail because they are weak, they fail because of fatigue and defect propagation.

Fracture rates of IPS Empress all-ceramic crowns: a systematic review
Heintze, Rousson
International Journal of Prosth., 2010

Most fractures 3-6 years
Ceramic materials do not fail because they are weak, they fail because of fatigue and defect propagation. Ceramic fatigue is dramatically accelerated with sliding contact in a moist environment.

Understanding All-ceramic material limitations

Single Load to Fracture

Typical failure mechanism with thin samples

Damage to inner and outer surfaces significantly weakens

Cone Crack

Sliding contact fatigue damage in layered ceramic structures

Kim, Kim, Thompson, Zhang

JDR, 2007

More prone to occur with thicker samples and softer ceramics

Inner Cone Crack

Outer Cone Crack

Effect of surface damage

Simulated Dentin

Overview: damage in brittle layers structures from Lawn, B. et al., J. Material Research, 2002

Layered All-Ceramics are more likely to fracture than monolithic ceramics

Results in surface defects which have been shown to increase abrasion potential

Uniaxial=20,000 cycles
**Understanding All-ceramic Material Limitations**

- **Crack depth in microns**
  - Number of cycles @ 120 N
  - 10^0
  - 10^1
  - 10^2
  - 10^3
  - 10^4
  - 10^5

**Sliding Contact Fatigue Damage in Layered Ceramic Structures**

- **Failure**
- Inner Cone Crack

---

**Proven Principles**

- Good science happens slowly!
- With ceramic materials, the clinical (in-vivo) performance is routinely inferior to laboratory (in-vitro) results.
- With bonding procedures, clinical (in-vivo) performance is routinely inferior to laboratory (in-vitro) results.

**Fracture rates of IPS Empress all-ceramic crowns-a systematic review**

- "...the material should not be used in patients with confirmed or suspected bruxism."

**The Evidence**

- "A ceramic layer of sufficient thickness needs to be ensured."
"...thickness, rather than inherent properties of the material, is the most important factor relating to the load required to initiate radial fractures."

Rekow, D., Zhang, Y., Thompson, V. 
Compendium, July, 2007

"As the thickness of the ceramic increases, the load required to initiate fracture increases dramatically, as indicated by this term appearing as the square of the thickness."

Hand-stacked feldspathic 
Feldspathic 
85-110 MPa 
Lithium disilicate 
360-400 MPa 
Fracture-proof in dimensions of 1 mm or less

Effect of ceramic thickness on load to failure

Load to radial crack (N) 
0 100 200 300 400 500 600 700 
Ceramic thickness (mm) 0.5 1.0 1.5

Monolithic is more fracture resistant than layered

Wear resistance equivalent to or lower than enamel

Total wear resistance!!
Does a material that will not wear dangerously reduce our ability to adapt to changes in the stomatognathic system?

Wear resistance equivalent to or lower than enamel is perhaps the most important material property. WEAR RESISTANCE is perhaps the most important material property.

Each of these is critical, but WEAR RESISTANCE is perhaps the most important material property.

How do we frequently see the system change?

Changes in occlusion related to changes in the TMJ:

Changes in occlusion related to changes in the TMJ:

Changes in occlusion related to changes in the TMJ:

Estimated to occur in 1/3 of our patients, irrespective of symptoms.

Tooth Wear or Tooth Migration (Attrition, Erosion, Abrasion, or Fracture):

Changes in occlusion related to changes in the TMJ:

Changes in occlusion related to changes in the TMJ:

Changes in occlusion related to changes in the TMJ:

The System:
Non-Adaptive

Joint Degeneration
Anterior Open Bite

Image courtesy of Dr. Drew Swenda

Decrease in the Fossa-Ramus VD
Increase in the Anterior VDO
Increase in the Anterior Facial VD

Adaptive

Patient's Concerns
"Splaying" of Max. Anteriors...
...with ⬆️ diastemas
Reverse smile line
Wear on lingual of anteriors

Adaptive Pt.

Adaptive Pt.

Adaptive Pt.

Adaptive Pt.

"Splaying" of Max. Anteriors...
Wear on lingual of anteriors
Extrusion of mand. anteriors

Adaptive Pt. #1

Almost no wear on premolars
Minimal wear on molars
Extremely short clinical crowns - second molars

Patient's Concerns
"Splaying" of Max. Anteriors...
...with ⬆️ diastemas
Reverse smile line
Wear on lingual of anteriors
Extrusion of mand. anteriors
Adaptive Pt. #1

How did this pt. adapt?
- Intrusion of posterior teeth
- Migration of anterior teeth

Question??
What would happen if these were restored with implants?
- Wear of anterior teeth

What would happen if these were restored with a material that will not wear?

Non-Adaptive

Piper M, Piper Level 1 Manual: Comprehensive TMJ Science

Avoiding System Failure

Terminal teeth take a beating!

"With second molars I give my patients two choices...
they can choose gold or find another dentist!"

Dr. Jack Turbyfill

Changes in occlusion related to changes in the TMJ

CHANGES IN THE STOMATOGNATHIC SYSTEM?

CHANGES IN OCCCLUSION RELATED TO TOOTH WEAR

CHANGES IN OCCCLUSION RELATED TO CHANGES IN THE TMJ

Quantitative in vivo wear of human enamel

Occlusal contacts and tooth wear
Woda, et al, JPD, 1979

Occlusal tooth wear in the general population of Germany: Effects of Age, Sex, and Location of Teeth

Quantitative in vivo wear of human enamel

21 subjects (18-23 years old)
Complete dentitions
All restorative procedures accomplished prior to study
Enamel loss evaluated with measuring stereomicroscopes
Accurate to within 1µm
**Quantitative in vivo wear of human enamel**


**Wear data must be doubled since it occurs in both arches**

- Premolars (n=48)
- Molars (n=49)

**Wear in heavy bruxers is as much as 400-500 µm per year!**

- 88 µm SD=73 µm
- 153 µm SD=80 µm

**The Degree to Which Dental Attrition in Modern Society is a Function of Age and of Canine Contact**


- Wear in heavy bruxers is as much as 400-500 µm per year!

**Dental wear is a general physiological phenomenon found in every civilization at every age.**

"Dental wear is a general physiological phenomenon found in every civilization at every age."

**The wear of a dental restoration must always be related to the stomatognathic system in which the restoration has to function.**

"Ideally, a restoration should have a wear resistance similar to that of enamel."

**Occlusal contacts and tooth wear**

Woda, et al, JPD, 1979

- 22 Subjects (18-50 years old)
- Complete dentitions
- No cases of periodontal disease, bruxism, TMD, restorations, or history of occlusal or orthodontic therapy
- Class I molar relationship with good tooth alignment and minimal wear
- Impressions were made and wear evaluated

**Occlusal contacts and tooth wear**

Woda, et al, JPD, 1979

- All of the teeth except the lateral incisors displayed facets
- Working side wear facets were found in all posterior teeth
- Nonworking facets were found in all first and second molars, in 82% of second premolars, and in 58% of first premolars
- Occlusion with canine protection evolves toward a group function type after canine wear

**Occlusal tooth wear in the general population of Germany: Effects of Age, Sex, and Location of Teeth**


- 836 Subjects (20-59 years old)
- Age was the only inclusion criterion
- The presence of tooth wear was found to be located in the anterior teeth, which agreed with the findings from several other studies
- The guidance pattern (anterior guidance) often changes to group function...
"The introduction of metallic or ceramic prosthetic surfaces [which are more wear resistant than enamel] will prevent normal abrasion and will counteract physiologic changes of the dentition’s surface."

Proven Principles

- Wear is going to occur in all of our patients
- Anterior guidance moves toward group function is most patients
- When we use a material more wear resistant than enamel some other part of the system will likely suffer
- The stomatognathic system is constantly changing!

All-ceramic Options

- High Strength Cores
  - Zirconia Core
    - 900-1200 MPa
  - Monolithic Zirconia
  - Alumina Core
    - 350-400 MPa
- Bonded Ceramics
  - Leucite Reinforced
    - 130-170 MPa
  - Lithium Disilicate
    - 360-400 MPa

All-ceramic Options

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Distribution of restoration types produced by Glidewell Laboratories in December 2013:

- Lithium Disilicate: 44%
- Anterior Posterior: 14%
- BruxZir Solid Zirconia: 31%
- Clinical Zirconia: 15%
- Porcelain Fused to Metal: 10%
- Full Cast: 0%
- Other: 3%

Growth of BruxZir Restorations

<table>
<thead>
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<th>Year</th>
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Number of Units per Month

- 0
- 10000
- 20000
- 30000
- 40000
- 50000
- 60000

DiTolla M, Dental Laboratory

Occlusal Contacts and Tooth Wear

Woda, et al, JPD, 1979

What will happen if tooth attrition is more rapid than restoration wear?

What will happen if restorations wear at different rates?
Two-body wear of monolithic, veneered and glazed zirconia and their corresponding enamel antagonists


"The glazed ceramic surfaces caused more wear on antagonist enamel specimens than the rough or smooth specimens."

"The material that caused the least amount of wear on opposing enamel was lithium disilicate ceramic (e.max)."

Ideally, a restoration should have a wear resistance similar to that of enamel.

Three-body wear potential of dental yttrium-stabilized zirconia ceramic after grinding, polishing, and glazing treatments


"...none of the tested zirconia ceramics showed any wear after the simulation tests"

Zirconia Does Not Wear!

Total Wear Resistance

Zirconia??

Transformation Toughening

Tetragonal

Stress induced crack propagation

Monoclinic

Increase in volume

Increase in roughness

Decrease in strength

Which material has a wear resistance most similar to enamel?

Vita Omega 900
Cercon Ceram Kiss
Creation Zi-F
Lava Ceram

186.1 ± 33.2
232.9 ± 66.9
222.4 ± 43.5
188.3 ± 132.8

Enamel 274.1 ± 187.4

Which material has a wear resistance most similar to enamel?

Ceramic Material

Zeno Zr-Bridge 0.0
Lava
Digizon
Ceramill Zi-T-YTZP
Cercon Base

0.0
0.0
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Enamel 274.1 ± 187.4

Which material has a wear resistance most similar to enamel?
Low Temperature Degradation (LTD) is responsible for grain push-out, increased roughness, increased wear, decreased hardness, and loss of strength (20% decrease in fracture strength), which may lead to performance deterioration.

In 2001 several hundred premature hip prosthesis failures were reported.

Under hydrothermal changes, an undesired phase transformation from tetragonal phase to the weaker monoclinic zirconia can occur on the surface of the monolithic zirconia FDPs (fixed dental prosthesis). This is combined with an increase in the surface roughness, resulting possibly in high abrasion of the antagonist enamel.

Influence of Low Temperature Environmental Exposure on the Transformation in Zirconia - Lessons Learned and Future Trends


J American Ceramic Society, 2009

Journal of Prosthodontics, 2012

J American Ceramic Society, 2009


Chevalier J, J Biomaterials, 2006
Monolithic Zirconia

**REMEMBER!!!**

Zirconia will not break.
Zirconia will not wear.
Zirconia may aggressively wear opposing surfaces if not carefully adjusted and polished.
Zirconia may become rougher with function and LTD.

**Sacrificial Device**

Part of a system that is intentionally engineered to fail under excess stress so that the sacrificial part is engineered to fail first, and thus protect other parts of the system.

**How the System Adapts to Change**

- Change in occluding surfaces
- Periodontal response
- Mobility
- Tooth migration
- Tooth intrusion
- Neuromuscular adaptation
- Occlusal disharmony

**How the System Adapts to Change**

- Surface wear
- Tooth fracture

**Surface wear**

**Tooth fracture**

**The Patient is a Dentist!**

"...it's night and day the change after getting that thing off."

Restoration is replaced & patient is asymptomatic.

**76.1%**

**23.9%**

**The Patient Provided Two Sets of Study Casts**

One set from immediately after restoration delivery.
One set from two years post-op just prior to replacement.

**Patient Identifies #15 as the First Point of Contact**

1 year, 9 months.

Techscan indicates that initial contact & most of the occlusal force is on #15.

**Monolithic Zirconia Restoration Placed on #15 in Dec. 2012.**

**The Patient is a Dentist!**

"...it's night and day the change after getting that thing off."

Restoration is replaced & patient is asymptomatic.

**Techscan-2014**

76.1%

23.9%
What may happen if these are both monolithic zirconia with implants?

**MONOLITHIC ZIRCONIA**

**REMEMBER!!!**

Zirconia will not Break
Zirconia will not wear
Zirconia may aggressively wear opposing surfaces if not carefully adjusted & polished
Zirconia may become rougher with function and LTD

**How the System Adapts to Change**

- Neuromuscular Adaptation
- Neuromuscular Disharmony
- Occlusal Disharmony
- System Failure

- Change in occluding surfaces
- Surface wear
- Tooth Fracture
- Change in occluding surfaces
- Surface wear
- Tooth Fracture
**Zirconia will not Break**

**Remember!!**

The system constantly changing.
Zirconia may demonstrate an uneven mean opposing surface if not carefully adjusted & polished.

**Zirconia demonstrates no adaptive capacity**

All-ceramic or metal-ceramic tooth supported fixed dental prostheses (FDPs)? A systematic review of the survival and complication rates. Part I: Single crowns (SCs).


"Zirconia based crowns exhibited significantly more loss of retention than metal-ceramic crowns."

"Crowns made out of densely sintered zirconia cannot be recommended as a primary treatment option, due to an increased risk of chipping of the veneering ceramic and loss of retention."

"Reductions in bond strength up to 87% for Panavia and 66% with RelyX Unicem were observed after 5 months of water storage."
**If we could bond zirconia, should we?**

**Retrievability?**

Most restorations require replacement—therefore "retrievability" should be a consideration.

### Table: Growth of BruxZir Restorations

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<tr>
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Glidewell Dental Laboratory

In the next 5-7 years we will have 60,000 zirconia restorations to "cut off" PER MONTH!

**Proven Principles**

The system is constantly changing.

The system is constantly ADAPTING!

Our restorations should also adapt.

Restorations Fail—therefore, we should consider retrievability.

Restoration fracture is not the worst mode of failure.

When we use a material more wear resistant than enamel some other part of the system will likely suffer.

**Is the best answer really a more wear resistant material?**

The activity that caused the change in the system will almost always continue.

**My Opinion**

A patient that is a bruxer, has significant wear, or has destroyed other restorations is the last patient in which these restorations should be placed.

**All-Ceramic Options**

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High Strength Cores

- **Alumina core**: 350-600 MPa
- **Zirconia core**: 900-1200 MPa

Bonded Ceramics

- **Feldspathic veneers**: 85-110 MPa
- **Leucite reinforced**: 130-170 MPa
- **Lithium disilicate**: 360-410 MPa

All-ceramic Options

- **Monolithic Zirconia**

Why Consider Bonded Ceramic Restorations?

- **Maximum esthetics**
- **Conservation of tooth structure**
- **Economics efficiency**
- **Metal-free restorations**

Conservative Bonded vs. Cemented Full Coverage

- ** ninth year post-op

“Why consider bonded ceramic restorations?”

- **John Kois**: The failure mode of veneers is different than the failure mode for full coverage crowns. In veneers we put the risk in the restoration, not the tooth.

“One of the most important factors in determining the longevity of the tooth/restoration complex is the amount of remaining tooth structure.”

- **Terry Donavan**

Conservative Bonded vs. Cemented Full Coverage

- **Simplify preparations and impressions**
- **metal-free restorations**

Conservative Bonded vs. Cemented Full Coverage

- **Only bonded all-ceramics satisfy all of the indications!**
One of the most important factors in determining the longevity of the tooth/restoration complex is the amount of remaining tooth structure.

John Kos

Conservative Bonded vs. Cemented Full Coverage

“Gable failure mode of veneers is different than the failure mode for full coverage crowns. With veneers we put the risk in the restoration, not the tooth.”

John Kois

High Strength Lithium Disilicate

Lithium disilicate e.max CAD-360 MPa
Lithium disilicate e.max Press-400 MPa

Sliding Fatigue in Water

Layered Zirconia Core Crowns
100K cycles@200N-100% failure
Metal-Ceramic Crowns
>300K cycles@>1100N
Lithium Disilicate (monolithic)
1mil. cycles@1100N or less 0 failures

The take-home
Steam Clean, Ultra-sonic, or carefully air abrade with glass beads!
Adjust with light pressure, keep wet & cool

Lithium disilicate 360-400 MPa
High Strength Lithium Disilicate
Steam Clean, Ultra-sonic, or carefully air abrade with glass beads!
Adjust with light pressure, keep wet & cool

“...the material.”

Dr. John Sorenson
Southwest Academy of Restorative Dentistry
Dallas, TX, January 17, 2013

Enamel Volume Loss-Two Body Wear

Material Volume Loss opposing enamel

Two-body wear of monolithic, veneered and glazed zirconia and their corresponding enamel antagonists

Prep retention and resistance

The bond to etched lithium disilicate is significantly stronger than the bond with leucite reinforced materials.

Bona, A. D., et. al.
J Adhesive Dent, 2000

Should e.max be bonded?

The evidence

“A relatively thin layer (100 microns) of resin luting agent bonded to both IPS Empress and IPS Empress 2 significantly increased the characteristic strength of the ceramics.”

Pagniano, R. P., Jr., et. al.
JPD, May, 2005

Prep retention and resistance...

Should e.max be bonded?

“The disruption of the bond at either interface results in a reduced ability of the ceramic to support a vertical load.”

Clelland, N. L., et. al.
JPD, January, 2007

Prep retention and resistance...

Should e.max be bonded?

 “… disruption of the ceramic-cement interface had a more detrimental effect on the load-bearing capacity of the simulated restoration than the disruption of the cement-dentin interface.”

Clelland, N. L., et. al.
JPD, January, 2007

Prep retention and resistance...

Should e.max be bonded?

For maximum strength, ceramics that can be etched should be bonded.

With tooth preparations that have adequate reduction (restoration thickness), retention form, and/or compromised ability to isolate – cementation with resin modified glass ionomer may be the preferred choice.

Lithium disilicate reinforced restorations

360-400 MPa

Fixed Partial Dentures with e.max

Survival rate of lithium disilicate restorations at 4 years: A retrospective study

Sulaiman, Delgado, Donovan.
JPD, 2015

21,340 restorations - 15,802 monolithic & 5538 layered

Data collected for 45 months from two commercial Dental Laboratory’s database systems

“Layered single unit crowns fractured at approximately twice the rate of monolithic crowns, but the fracture rate was still low” (1.83% vs 0.91%)

The failure rate for FPD’s (all monolithic) was 4.55% or almost 4 times that of single units.
**Fixed Partial Dentures with e.max??**

**THE TAKE-HOME**

- Single unit lithium disilicate restorations have an acceptable survival rate, particularly in the anterior region.
- Lithium disilicate fixed partial dentures should be used with extreme caution in the anterior region only.

**Fixed Partial Dentures with e.max??**

**THE TAKE-HOME**

- Layered single unit crowns fractured at approximately twice the rate of monolithic crowns, but the fracture rate was still low (1.83% vs 0.91%).
- Layered all-ceramics are more susceptible to fracture than monolithic ceramics.

**Lithium Disilicate Reinforced Restorations 360-400 MPa**

- The strongest BCR available today.
- Suitable for all single unit restorations, veneer thru full coverage.
- Current studies, both in vitro and in vivo, report excellent durability with single unit restorations.
- Monolithic or layered in a variety of translucencies.
- Widely available, familiar fabrication technique.

**Micro-layered Lithium Disilicate**

- Ideal for preps with compromised retention.
- Prep shade communication critical.
- Aesthetics improving with additional translucencies, currently a new multi-layer ingot.
- For maximum strength, e.max should be etched and bonded.
If your patient presents with evidence of bruxism including wear of the canines and exposed dentin in the molars, which of the following would be indicated if you had to restore the occlusal surface of the mandibular second molars?

a. a gold crown
b. a monolithic alumina restoration
c. a monolithic zirconia restoration
d. any of the above

Which of the following is true of monolithic zirconia restorations?

a. monolithic zirconia restorations wear excessively
b. monolithic zirconia restorations tend to discolor
c. monolithic zirconia restorations require preparations with significant retention
d. monolithic zirconia restorations often fracture

Which of the following does not occur on the surface of a monolithic zirconia restoration after transformation toughening?

a. The surface becomes smoother
b. The surface becomes rougher
c. The surface becomes weaker
d. A & C above

When a stress induced crack starts to spread through zirconia which of the following occurs?

a. transformation toughening – a transformation from monoclinic to tetragonal crystalline structure
b. low temperature degradation
c. transformation toughening – a transformation from tetragonal to monoclinic crystalline structure
d. catastrophic failure of the material

Which of the following ceramic materials has the lowest fracture strength?

a. Zirconia
b. Feldspathic porcelain
c. Lithium disilicate
d. Leucite

Answers:

a. monolithic zirconia restoration
b. monolithic zirconia restorations require preparations with significant retention
c. transformation toughening – a transformation from monoclinic to tetragonal crystalline structure
d. Leucite