Study Title: **Removable Partial Denture Abutments Restored with Monolithic Zirconia Crowns**

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Removable Partial Denture Abutments Restored with Monolithic Zirconia Crowns: A Randomized Controlled Trial

This study will investigate the use of highly esthetic, second and third generation multi-layer zirconia crown materials to restore removable partial denture abutment teeth. All performed treatment will be the standard of care and to the usual and customary standards used in United states dental clinics for crown and RPD procedures. Treatment subjects will have RPD abutment teeth restored with either Noritake Katana STML (anterior teeth) or HTML (premolars and molars) zirconia crowns, and periodically evaluated for 60 months following RPD delivery. Outcomes will be compared to a similarly treated control group restored with metal, metal-ceramic, or a combination of metal and metal-ceramic crowns.

Following informed consent, subjects will be randomly assigned using an internet program (https://www.randomizer.org/) to either a treatment (zirconia abutment tooth crown) or control (metal or metal-ceramic abutment tooth crown) group. Using information from the oral examination, articulated diagnostic casts will be evaluated , the RPD design confirmed, and the need for a crown on one or more abutment teeth verified. Enrolled subjects will be given oral hygiene instruction at the beginning of the study. They will also be instructed to brush their teeth twice daily using an OTC fluoride dentifrice of their choice. They will also be asked to use a 0.05% NaF oral rinse for 1 minute daily.

Abutment teeth must be in function with the opposing arch and vital at the beginning of the study. Vitality will be be determined using a synthesis of history, percussion, palpation and pulp testing. Pulp tests will be conducted using cold and an EPT, and the facial, lingual and occlusal (incisal) surfaces of all abutment teeth will be tested for responsiveness. If abutment tooth vitality is confirmed, teeth requiring surveyed crowns will be prepared and restored using standardized clinical and laboratory guidelines.

Abutment teeth restored with metal and zirconia crowns will be prepared and restored using the following clinical and laboratory guidelines. The margin will be a circumferential chamfer prepared to a depth of 0.5 mm with a rounded internal line angle and a 90° cavosurface exit angle. Margin height will be at or slightly coronal to the free gingival margin where possible. Axial surfaces will be prepared with a total occlusal convergence of >6° but not to exceed 20°. Incisal and facial surfaces will be reduced 0.7-1.0 mm. Functional surfaces will be reduced to 1.0 mm of opposing tooth clearance with the exception of under rest seats, where opposing tooth clearance will be 2.0 mm. At completion, the prepared tooth should have a height to base ratio of 0.4. If inadequate retention and resistance form is identified following preparation of axial walls, supplementary grooves will be added, the number and location of which are at the discretion of the investigator. Final impressions will be made using PVS in a custom tray (Extrude) and poured in type V dental stone (Jadestone). Following fabrication, the working cast will be articulated, tripoded, and the die(s) sectioned, trimmed and scanned (3Shape D2000 laboratory scanner or equivalent). The crown(s) will be waxed to full contour. Rest seats, undercuts and guide planes will then be developed in wax. Once the waxup has been surveyed and finalized, it will be secured to the scanning platform and a new scan performed with the waxup in place. The data file with the die scan will be merged with the file that contains the waxup. The merged file will then be transmitted to a designated production facility where the zirconia crown(s) will be milled. Canines will be milled using Noritake Katana STML zirconia and premolars and molars will be milled using Noritake Katana HTML zirconia. Once the crown(s) are returned and the margins, contacts, occlusion and contours clinically verified, they will be luted using a self-adhesive resin-based cement (RelyX Unicem 2).

Porcelain-fused-to-metal (PFM) crowns will be prepared and restored using a standard protocol utilizing the following guidelines. Posterior crowns will have metal occlusal surfaces with the porcelain-metal junction on the occlusal surface at half the distance between the central groove and the buccal cusp tip. Mesial, distal and lingual surfaces will be in metal, and the crown will have a disappearing metal margin on the facial surface. The facial preparation from mesiofacial to distofacial line angles will be a heavy chamfer or modified shoulder 1.0-1.2 mm in depth with a rounded internal line angle and a 90° cavosurface exit angle. Mesial, distal and lingual chamfer margins will be prepared to a horizontal depth of 0.5 mm. Facial margin height will be at or slightly apical to the free gingival margin. Mesial, distal and lingual margin height will be at or slightly coronal to the free gingival margin if possible. Functional surfaces will be prepared with opposing tooth clearance of 1.5 mm with the exception of under rest seats where opposing tooth clearance will be 2.0 mm. Nonfunctional cusp reduction will be 1.0 mm. Final impressions will be made using PVS (Extrude) in a custom tray and poured in type V dental

stone (Jadestone). Following working cast fabrication it will be articulated, tripoded, and the die(s) prepared for conventional laboratory crown fabrication. Conventional (all-metal and PFM) surveyed crowns will be fabricated using noble and high-noble casting alloys and PFM crowns will use feldspathic porcelain as a veneering ceramic. Once the crown(s) are returned and the margins, contacts, occlusion and contours clinically verified, they will be luted using a self-adhesive resin-based cement (RelyX Unicem 2).

Qualifying RPD designs may be Kennedy class I-IV with up to two modification spaces, and will be designed using a standardized protocol. Maxillary major connectors may consist of a complete palatal plate, modified palatal plate, anterior-posterior palatal strap or palatal strap. Mandibular major connectors will consist of either a lingual plate or a lingual bar. Frameworks will be fabricated from nickel-chrome alloy (Ticonium), the denture bases acrylic resin (Lucitone 199), and artificial teeth will be DENTSPLY Trubyte IPN Portrait. To meet the definition of an RPD abutment tooth it must host a direct retainer consisting of an occlusal or cingulum rest, a proximal plate and a retentive clasp. Reciprocation must be provided in the form of a plate, reciprocating clasp or minor connector and rest. The plan for occlusion will be based upon the number and distribution of remaining natural teeth. If an arch opposing the RPD is edentulous and restored by a removable complete denture, then natural and artificial teeth will be arranged in bilateral balance. If anterior guidance is present on natural teeth in both arches it will be preserved so that artificial RPD teeth contact opposing teeth in maximum intercuspation only.

Clinical assessments, procedures and annual examinations will be performed in the University of Kentucky College of Dentistry second, third, and fourth floor student clinics. Clinical procedures will be performed by third and fourth year dental students, and clinical supervision for these procedures will be provided by licensed, calibrated investigators.

ELIGIBILITY CRITERIA

Study participants must be between the ages of 25-70 when they enroll in the study and be available for follow-up for five years following the conclusion of their treatment. Patients must be able to speak and read English, understand the study and informed consent documents, and be eligible for care in the UKCOD student clinics. You will be excluded from the study if you have any chronic or degenerative condition which impairs your consent capability including:

- traumatic brain injury
- severe depression or bipolar disorders

- schizophrenia or other mental disturbance with an associated cognitive impairment
- stroke
- degenerative dementia or Alzheimer’s disease
- CNS cancer or cancer with CNS involvement
- Parkinson’s Disease
- persistent substance dependence
- chronic pain
- any disorder with secondary drug effects which may result in fluctuations in consent capacity

Participants must also be healthy enough to tolerate planned dental procedures. Patients may be excluded if they require antibiotic premedication before dental treatments, and if they have been diagnosed with any of the following:

- severe anxiety
- unstable diabetes or asthma
- unstable hypertension
- COPD
- ischemic heart disease
- HIV/AIDS
- renal insufficiency
- autoimmune or inflammatory disorders

Participants must also be capable of continuous participation and follow-up in the study once they enroll, so may be excluded for the following:

- pregnancy
- planned extensive leave such as
    - sabbatical
    - overseas military assignments
    - permanent relocation outside of the University of Kentucky treatment corridor

Finally, subjects must be stable with respect to caries (decay) and periodontal (gum) disease, they must demonstrate proper care for remaining teeth, and be willing to use an oral rinse as directed.

Patients participating in the study must have the following treatment requirements and conditions:

- patients must have been treatment planned for a removable partial denture (RPD) in one or both jaws
- patients must require at least one crown on an RPD abutment tooth
- abutment teeth requiring crowns must be in contact with opposing teeth (or dentures)
- abutment teeth must be healthy and not in need of root canal therapy at the time of their enrollment

LOCATION

The clinical procedures for this study will be conducted at the University of Kentucky College of Dentistry student clinics on the second, third and fourth floors of the UK Chandler Hospital in Lexington, Kentucky. You will need to come to these clinical facilities approximately 15-25 times over the course of 9-12 months to complete planned treatment. Each of those visits will take about 3 hours. Following treatment completion investigators will want to evaluate you every 6-12 months for 5 years. The total amount of time you will be asked to volunteer for this study is approximately 70 hours over the next 5 years.

WHAT WILL PATIENTS BE ASKED TO DO?

Participants will have a dental examination, study documents will be reviewed, and informed consent obtained. You will be given oral hygiene instruction by your student dentist, and asked to brush remaining teeth twice daily, floss once daily, and rinse for 1 minute daily with ACT®, an over the counter 0.05% sodium fluoride oral rinse.

Investigators then ask that you complete your restorative dental treatment as planned, and care for your teeth as instructed. If you decide to participate in this study, we ask that you not enroll as a subject in any other research until this investigation has concluded.

A dental treatment plan that includes a removable partial denture and one or more crowns typically requires 15-25 visits. These visits usually consist of 1-3 mornings or afternoons a month for 9-12 months until treatment is complete. The timeline for treatment is similar whether you are treated in a private office or in a student clinic. The difference is that students who provide care for patients require professional supervision, so each appointment is typically for an entire morning or afternoon, rather than an hour or two as would be the case in a private practice.

Crown procedures are routine dental treatment, and typically require 2-4 visits to complete. Removable partial denture procedures typically require 3-5 visits to complete. Removable partial dentures must be started after any necessary crowns are completed. For this reason, the removable partial denture is usually the last part of your treatment plan to be finished.

The part of your treatment that is the focus of this investigation is the crown material that will be used for the tooth or teeth that will be clasped by your removable partial denture. The treatment group will have teeth restored with zirconia. Zirconia is a new type of all-ceramic crown material that is already widely used in dentistry to make crowns for natural teeth and implants. This material is of interest because it is tooth colored, exceptionally strong, and requires less tooth structure removal than alternative materials. ***We are investigating whether zirconia crowns will last as long as conventional crowns when used with a removable partial denture. There are very few scientific reports on how well this material lasts when used in this manner.***

Participants who will have their crowns made from zirconia will be followed for 5 years, and their oral health will be compared to another group of patients restored with all-metal or PFM crown materials. If there are significant differences between the outcomes of the two groups, investigators can use this information to make treatment recommendations to future patients. Since this is a randomized controlled study, you will be randomly assigned to the PFM ***or*** monolithic zirconia crown group. This means that you do not get to choose which material investigators use to make your crown.

The following chart provides a general timeline for a patient needing one crown, and a removable partial denture to restore missing teeth in one of your jaws. This represents the simplest sequence of procedures that a qualifying subject will need to complete. All appointments in the student clinics are 3 hours in length.

Appointment Number	Timeline	Procedure
1	Day 1	Examination, preliminary impressions, x-rays, faculty consultation
2	Week 2	Records, complete any unfinished examination or x-ray procedures, introduction to clinical study and review of consent documents
3	Week 3	Treatment planning. Financial arrangements. Meet with investigator. Review clinical study and informed consent documents
4	Week 4	Finalize treatment plan, review study documents, and clarify any questions patients have regarding treatment. If they agree to participate in the study the informed consent document must be signed by this time and random assignment will be made.
Whether a patient participates in the study or not, diagnosis, treatment planning and financial arrangements take at least 3 and commonly 4 appointments before clinical treatment is started in UK student clinics.		
5	Week 5	Replace any old fillings in abutment tooth and prepare it for a PFM or zirconia crown (anesthesia required). Make temporary crown.
6	Week 7	Finish preparation (anesthesia required). Final impression. Recement temporary crown.
7	Week 8	Bite record of how the upper and lower teeth contact. Shade
8	Week 12	Cement crown (anesthesia sometimes required). Preliminary impression for removable partial denture.
9	Week 13	Removable partial denture framework impression using custom tray
10	Week 16	Secondary impression to accurately record the area missing the teeth (called an “altered cast” impression)
11	Week 18	Bite records including face-bow. Selection of shade, shape and size of artificial teeth.
12	Week 20	Try-in of artificial teeth to evaluate their color, shape and position

13	Week 23	Delivery, bite adjustment and take-home instructions
14	1-2 days later: Week 23	Follow-up for adjustments
15	Week 24	Follow-up for adjustments
16	Week 26	Follow-up for adjustments
The appointments listed in the table above are considered the standard of care, and are necessary for treatment whether you participate in this investigation or not. If you decide to participate in the study, the following additional appointments are considered research, and will be needed for investigators to collect outcome information. You will not be charged for services provided in the following appointments		
17	6 months after appointment #13	2 hour follow-up examination with investigators (includes questionnaire)
18	1 year after appointment #13	2 hour follow-up examination with investigators (includes questionnaire and x-ray of abutment teeth)
19	2 years after appointment #13	2 hour follow-up examination with investigators (includes questionnaire and x-ray of abutment teeth)
20	3 years after appointment #13	2 hour follow-up examination with investigators (includes questionnaire and x-ray of abutment teeth)
21	4 years after appointment #13	2 hour follow-up examination with investigators (includes questionnaire and x-ray of abutment teeth)
22	5 years after appointment #13	2 hour follow-up examination with investigators (includes questionnaire and x-ray of abutment teeth)

Participants will be randomly assigned to either an experimental group (monolithic zirconia) or a control group (PFM). Random assignment means that your group assignment is by chance, similar to a coin toss. An internet-based, random number generator will be used to make group assignments. Since there are only two treatment groups, the chance of being assigned to either group is 50%.

POSSIBLE RISKS

Risks specific to this study include the following for zirconia crown recipients: ceramic fracture, caries (decay along the border of a crown), faster wear of the ceramic material relative to conventional metals, faster wear of the removable partial denture framework due to contact with the ceramic, possible abscess of abutment tooth, and fracture or loss of an abutment tooth

Caries (decay along the border of a crown) is expected to occur occasionally in a five year follow-up period. Caries is the most common reason conventional metal and PFM crowns need to be replaced, and this may also be the case with all-ceramic crowns.

Ceramic fracture is also expected to occasionally occur in a five-year follow-up period. Ceramic fracture can be avoided if crowns are made entirely of metal. However this would be unsightly for teeth in the front of the mouth. Ceramic fractures have been reported for both PFM and all-ceramic crowns, largely with the veneering ceramic. Although the zirconia crowns used in this study are monolithic and do not have a veneering layer of weaker ceramic, it is possible that more fractures occur with this group compared to PFM crowns.

Wear of ceramic or removable partial denture framework material is expected to be rare, because there have been very few reported incidences of this in the scientific literature with conventional materials.

Radiographs (x-rays) will be taken before, during and after treatment. The radiation dose from a typical dental x-ray is about 1/80th of the typical background dose that we all receive every year. It is also about 1/7th of the annual safe dose limit dose (not including medical exposures) for members of the public and well below the levels that are considered to be a significant risk of any harmful effects. The ALARA radiation safety principle (as low as reasonably achievable) to minimize patient x-ray exposure will be followed by students and researchers at all times.

Possible abscess of abutment tooth is expected to be a rare-occasional occurrence in a five year follow- up period, consistent with historical norms for any teeth requiring conventional crowns.

Abutment tooth fracture within a five year period is expected to be a rare occurrence in either group. This is a more likely occurrence with teeth that are structurally weakened to begin with. Since participants must have vital, periodontally sound, caries (decay) free abutment teeth for study participation, abutment tooth fracture would be a highly unexpected occurrence.

Risks for permanent side effects from dental treatment in this study are identical to those receiving dental care outside of this study: permanent numbness to the lip or cheek following anesthesia, aspiration of loose foreign objects that are inadvertently dropped down patient's throats, and allergic reaction to a material or medication.

Permanent numbness of the lip or cheek can make speech, eating and facial expressions difficult, similar to people who experience a stroke.

Foreign body aspiration may block the airway and make breathing difficult, requiring surgical retrieval. Difficulty in breathing can range from mild to severe. Complete airway blockage can result in death.

Allergic reactions can also range from mild to severe. Severe reactions can result in death. Other allergic reactions may require administration of a medication to manage its severity. Allergies commonly go away with removal of the product or material that is causing the allergy.

If a subject becomes pregnant while receiving treatment, further radiographs and restorative care may be postponed until after childbirth. If a study subject is unknowingly pregnant at any time during the study, the risks to the embryo or fetus are minimal, and identical to those of a patient who chooses not to participate in the study.

Local anesthesia will be administered before crown procedures. Risks associated with this procedure include soreness, bruising, pain, infection, fainting, bleeding, allergic reaction, and permanent numbness associated with the nerves which are blocked.

Possible Risk/Side Effect	How often has it occurred?	How serious is it?	Can it be corrected?
Bruising	It may occur just after drug administration	Usually of short duration, 2-5 days	Yes. It will go away with time
Pain and soreness	Commonly occurs with anesthesia	Usually minor and of short duration	It will go away with time
Infection	It is extremely uncommon	Very serious	Yes, but may require antibiotics
Permanent numbness	It is extremely uncommon	The damage is permanent and can affect the rest of your health	No
Allergic reaction	Rare	Can be very serious	Yes, but may require administration of medications
Fainting	Rare	Usually minor and of short duration	Yes

STATISTICAL ANALYSIS

Power analysis indicates that approximately 80 participants will need to be enrolled (40 per group) to obtain long-term (60 month) oral health data. Participants who will have their crowns made from zirconia will be followed for 5 years, and their oral health will be compared to another group of patients restored with all-metal or PFM crown materials. Failure and complication rates of each material will be analyzed using random-effects Poisson's regression models to obtain summary estimates. Multivariate analyses will be used to determine significance for outcomes with overlapping dependent variables.