Distribution Statement

Distribution A: Public Release.

**DEPARTMENT OF THE ARMY**
ADVANCED EDUCATION IN GENERAL DENTISTRY 2-YEAR PROGRAM
SCHOFIELD BARRACKS DENTAL CLINIC
BUILDING 660 McCORNACK ROAD
SCHOFIELD BARRACKS, HI 96857

## THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: Fracture Strength of CAM/CAM versus Contemporary Bis-Acryl Provisional Crowns

Name of Candidate: MAJ Migdalia Eibl Torres
Master of Science Degree
June 10, 2021

All work has been completed to the satisfaction of the research committee.

THESIS/MANUSCRIPT APPROVED: DATE:

YARBROUGH.LISA.N.1232836403 Digitally signed by YARBROUGH.LISA.N.1232836403 Date: 2021.05.26 21:17:40 -10'00'

26 May 21

Lisa N. Yarbrough, COL, DC
Program Director, AEGD-2 Hawaii
Committee Chairperson

02 June 21

Nicholas D. Wilson, MAJ, DC
Assistant Program Director, AEGD-2 Hawaii
Committee Member

05 June 2021

Catherine F. Uyehara, PhD
Chief, Department of Clinical Investigation, TAMC
Committee Member

# FRACTURE STRENGTH OF CAD/CAM VERSUS CONTEMPORARY BIS-ACRYL PROVISIONAL CROWNS

A manuscript

Presented to the Faculty of the Advanced Education in General Dentistry, Two-Year Program,

United States Army Dental Health Activity, Schofield Barracks, HI

And the Uniformed Services University of the Health Sciences – Post Graduate Dental College

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Oral Biology

By

Migdalia Eibl Torres, MAJ, DC, USA

MAY 2021

DENTAL

Uniformed Services University

DISCLAIMER

By

MIGDALIA EIBL TORRES, MAJ, DC, USA
D.D.S, New York University College of Dentistry 2011
B.A., Amherst College 1999

Mentor Staffing By

NICHOLAS WILSON, MAJ, DC, USA
Certificate, Advance Education in General Dentistry-Two Year, Schofield Barracks, HI 2017
M.S., Oral Biology , Uniformed Services University, 2017
D.D.S., University of Colorado School of Dental Medicine 2011
B.S., Washburn University 2007

WEN LIEN, COL, DC, USAF
M.S., USAF Fellowship, Indiana University Dental Materials- 2014
Certificate, Advance Education in General Dentistry- Two Year, San Antonio, T.X. 2009
D.M.D., Case Western Reserve University 2001
M.S., University of Minnesota 1996
B.S., University of California Irvine 1994

And

LISA N YARBROUGH, COL, DC, USA
Certificate, Advance Education in General Dentistry-Two Year, Fort Bragg, N.C. 2005
D.M.D., University of Florida 1998
B.S., Florida State University 1994

Schofield Barracks, HI
May 2021

## ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my AEGD-2yr Assistant Program Director, MAJ Nicholas Wilson; Research Mentor COL Wen Lien; AEGD-2yr Program Director, COL Lisa Yarbrough; AEGD-1yr Ft. Jackson Residency Director, LTC Brandon Gage; AEGD-2 Resident MAJ Tina L Gray; Research Team Member, Mr. Wayne Ichimura and Statistician, Mr. Michael Lustik for their support, guidance, and expertise throughout this research project. To my husband, Holger J. Eibl for his unwavering love and support, I am truly thankful.

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled:

"**Fracture Strength of CAD/CAM versus Contemporary Bis-acryl Provisional Crowns**"

Is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

**MAJ Migdalia Eibl Torres**
**Comprehensive Dentistry Residency**
Uniformed Services University
Date: **05/31/2021**

**Abstract**

FRACTURE STRENGTH OF CAD/CAM VERSUS CONTEMPORARY BIS-ACRYL PROVISIONAL CROWNS



Presented by: Migdalia Eibl Torres, MAJ, DC
Eibl Torres, M[1], Wilson, N[1] , Lien, W[2], Lustik, M[3] , Yarbrough, L[1]
[1]AEGD-2, Schoffield Barracks Dental Clinic, [2] USAF Dental Research, [3]Dept Clinical Investigation, Tripler Army Medical Center


**Introduction:** Provisional restorations have an important role in prosthodontic treatment, designed to protect teeth until delivery of a definitive restoration. CAD/CAM milled and traditional chair-side provisional fabrication techniques are widely used in clinical practice. Despite the advantages of CAD/CAM, direct chairside fabrication of provisional restorations using bis-acryl material is still a common procedure due to convenience and low costs. The investigation of contemporary bis-acryl materials will aid the clinician in making educated decisions on which material to choose for provisional restorations.

**Objective:** To compare the fracture strength and mode of fracture of CAD/CAM milled provisional crowns versus directly fabricated contemporary bis-acryl material under a laboratory environment.

**Methods:** Bis-acryl based materials, Luxatemp Ultra (LT, DMG) and LuxaCrown (LC,DMG) were used to fabricate provisional crowns utilizing conventional direct technique. Polymethyl methacrylate Telio CAD (TC, Ivoclar Vivadent) and acrylate polymer Vita CAD-temp (VC, Vita) were milled from monolithic blocks with CAD/CAM technology. Crowns were cemented with temporary cement (TempBond NE, Kerr) onto 3D-printed photopolymer resin model dies (Formlabs, n=10/group). A universal testing machine (MTS 858 Mini Bionix II test system) applied a compression load at a crosshead speed of 1 mm/min to individual samples until failure. The average value at failure and the mode of fracture were recorded.

**Results:** Maximum force at failure for each group (Mean $\pm$ SD, N) was 1547$\pm$443 for TC , 879$\pm$ 194 for LC 747$\pm$ 294 for VC, and 715 $\pm$ 159 for LT ($p<0.001$ overall and for each pairwise comparison with TC). Bis-acryl materials were more likely to have minimal crown fracture than the CAD/CAM materials (75% vs. 40%, $p=0.054$).

**Conclusion:** Fracture strength was significantly higher for TC compared to other materials. While failure load was lower for bis-acryl materials compared to TC, fracture mode was minimal. Failure load for LC tends to be higher than LT, but difference may not be clinically relevant. Fracture strength appears to be material dependent rather than on mode of fabrication.

# TABLE OF CONTENTS

Abstract .......... v

LIST OF TABLES .......... vii

LIST OF FIGURES .......... viii

LIST OF ABBREVIATIONS .......... ix

Background .......... **Error! Bookmark not defined.**

Methods and Materials .......... 4

Results .......... 9

Discussion .......... 11

Conclusion .......... 12

References .......... 14

# LIST OF TABLES

Table 1. Burke's classification of fracture pattern .......................................................8
Table 2. Overview of fracture strength of CAD/CAM and bis-acryl provisional crowns ..........................................................................................................9
Table 3. Chi-squate test and Fisher's exact test based on dichotomizing fracture pattern as Type I vs > Type I..........................................................................11

# LIST OF FIGURES

Figure 1. Digital workflow to fabricate SLA dies; d: SLA and Master dies. ................6
Figure 2. Provisional crowns cemented to SLA fabricated dies...................................7
Figure 3. Specimen mounted on Universal Testing Machine .......................................8
Figure 4. Fracture strength of provisional crowns. ......................................................9
Figure 5. Percent of samples by material type with minimal or greater than minimal crown fracture.........................................................................................................10
Figure 6. Fracture patterns of all crown materials tested ...........................................10

# LIST OF ABBREVIATIONS

LC ----------------LuxaCrown
LT ----------------LuxaTemp
PMMA----------- Polymethyl methacrylate
TC ----------------Telio CAD
VC ---------------Vita CAD

## BACKGROUND

Provisional restorations have important roles in prosthodontic treatment. They are designed to protect the pulp, maintain tooth positional and occlusal stability, and preserve inter- and intra-arch relationships during the period between tooth treatment and delivery of a definitive restoration [1]. To achieve this, they are usually made to be not only biocompatible but also cleansable with adequate strength, retention, and esthetics to safeguard gingival health [2, 3]. Furthermore, provisional restorations can also serve to aid diagnostics and treatment planning so patient outcomes are optimized [1, 4]. In some cases, provisional crowns may need to persist and function for extended periods so time-dependent therapeutic progress such as endodontic, periodontal, and implant treatments can be monitored [5, 6]. Consequences of ill-fitted provisional restorations can include problems with function and esthetics, open margins, recurrent caries, and abutment tooth movement, all of which can delay delivery of permanent restorations [6, 7]. In order to manufacture a provisional that meets clinical requirements, clinicians must base material selection decisions on mechanical properties, handling capabilities and biocompatibility [8]. Currently, there is not a material that encompasses all desirable characteristics for fabricating an ideal provisional restoration [9]. A variety of materials and techniques for the fabrication of provisional restorations is readily utilized in clinical practice.

Primary modes of provisional fabrication include direct and indirect methods [10, 11]. Direct fabrication is accomplished by utilizing a wax-up or impression matrix of the unprepared tooth. First, hand-mixed or auto-dispensed provisional materials from an auto-cartridge is injected into the matrix and applied intraorally on the prepared tooth [2, 12]. After setting, the provisional is removed from the matrix, trimmed and polished. Typically, provisional materials that are used to directly fabricate provisional restorations include polymethyl methacrylate (PMMA) and bis-acryl resins. For indirect techniques, the restoration is made in a dental lab, utilizing a master die made either from an impression of the tooth preparation or from digital impression [12, 13]. A third way to fabricate indirect fabrication is using CAD/CAM technology, which takes advantage of digital design and rapid prototyping to mill a restoration from a pre-polymerized block of material [13].

PMMA, derived from the polymerization of methyl methacrylate monomer, has been used to fabricate provisional crowns and fixed dental prosthesis since the 1940s [14]. Historically, this material was hand mixed from powder and liquid formulations and was used to create provisionals that exhibited relative durability, polish and repairability at a low cost. PMMA materials are comprised of monomethacrylates which create linear polymers of low molecular weight that do not cross-link with other polymer chains, resulting in lower strength and rigidity when compared to contemporary provisional materials[2-4]. The exothermic nature of the polymerization reaction of this material as well as cytotoxicity of free, excess monomer can potentially cause damage to pulpal tissues [8, 14]. Traditional PMMA exhibits high shrinkage, compromising marginal fit. A disadvantage of hand mixing is the introduction of flaws in the material due to air entrapment and incomplete mixture of material which can result a decrease in strength and an increase in wear as compared to bis-acryl materials [3]. Due to some of PMMA's undesirable qualities such as disagreeable odor, exothermic properties and brittleness, contemporary materials like bis-acryl resins gained popularity in clinical practice [15, 16].

Bis-acryl provisional material was developed to surpass some of the disadvantages of PMMA. This material exhibits relatively low shrinkage, good marginal adaptation, bio-compatibility with periodontal tissues, a lower exothermic reaction, high polishability, and esthetics [17, 18]. Bis-acryl materials have a rigid, cross-linked structure due to multifunctional monomers that allow for cross-linking with other polymeric chains [3, 19]. They also contain inorganic fillers, which help to distribute loading stresses, prohibit crack propagation, and increase elastic modulus, strength, and wear resistance [3, 19, 20]. Several studies have found that bis-acryl provisionals have superior mechanical properties in terms of hardness [21-23] and flexural strength [5, 9, 20] when compared to hand-mixed powder and liquid formulations of PMMA**.** The matrix type, degree of conversion, filler surface treatment, and inter-particle distance of bis-acryl might influence mechanical properties in a similar way as resin composites [3, 24].

Bis-acryl material is commonly used for fabrication of chair-side provisionals in clinical practice. The material is dispensed using automix cartridge systems, which provide clinicians with a uniform consistency that is easy to manipulate using indirect techniques [25, 26]. Automixing allows for proportional and consistent mixing that contributes to strength as compared to traditional PMMA [20]. Although this technique decreases the potential for introduction of air entrapment, in clinical practice, porosities can also be introduced by the operator, which can compromise mechanical strength [27]. Other disadvantages have been shown in which initial strength of bis-acryl material is compromised due to incomplete polymerization and is at their weakest, during the 10 minutes after mixing [15]. Afterwards, flexural strength gradually increases and reaches its maximum after 24 hours of fabrication [15, 28, 29]. Early fractures of provisionals made with self-cure bis-acryl materials have been shown to occur, which can lead to unscheduled replacement or repairs [30]. In addition, bis-acryl provisionals have poor repairability [8] and repairing of bis-acryl results in significantly decreased strength properties [31]. It is recommended that a new provisional is fabricated instead of repaired, resulting in increased patient appointment time [31].

The advent of CAD/CAM technologies has offered clinicians the option of manufacturing not only definitive restorations, but also provisional restorations. CAD/CAM technology entails use of an intra-oral scan to generate a digital impression, allowing the operator to digitally design a restoration which is then fabricated from a pre-polymerized block of material by a milling unit. Industrially fabricated CAD/CAM PMMA blocks improved the shortcomings of hand-mixed PMMA since these materials have been polymerized under standardized conditions [32]. Polymerization shrinkage and excess monomer are controlled during manufacture of monolithic blocks [33, 34]. Milling a restoration from a monolithic block minimizes the formation of porosities from air inclusion seen in directly fabricated techniques; thereby, a milled restoration generally has improved mechanical properties [35]. Past studies found that Telio CAD crowns offered superior marginal adaptability and mechanical strength than traditional PMMA [16, 36] and were recommended for those restorations that were expected to serve as long term provisional [34, 37]. CAD/CAM fabricated provisional crowns have better marginal adaptation than bis-acryl crown, but no difference in flexural strength [7, 27]. CAD/CAM provisionals have significantly higher fracture resistance, surface hardness, and improved color stability than chairside fabricated provisional restorations [37]. Although there is limited in-vitro and in-vivo data on the durability of CAD/CAM versus bis-acryl materials, an in vivo/in vitro split study showed no significant difference in directly fabricated bis-acryl vs CAD/CAM fabricated provisional crowns in terms of fracture force or wear [33].

Despite the advantages of CAD/CAM, direct chairside fabrication of provisional restorations is still a common procedure employed by clinicians due to convenience and low costs [38]. The high costs of CAD/CAM machinery and armamentarium as well as space required for assembly of the computer and milling units are some drawbacks to this technology. In operational environments where dental treatment is rendered, CAD/CAM may not be available or accessible, therefore the use of chairside provisional techniques and materials are indicated. The autocartridge system is compact and portable, making it convenient to include in field dental equipment set-ups. Bis-acryl resins have been developed in recent years with advances in proprietary monomers, plasticizers, and inorganic filler technology to enhance mechanical properties and improve clinical performance [3, 8, 19]. The investigation of contemporary bis-acryl materials and their mechanical properties will aid the clinician in making educated decisions on which material to choose for provisional restorations. As new bis-acryl materials are developed, manufacturers claim improvement on the shortcomings of their predecessors and warrant further investigation as to their mechanical properties and performance in the clinical setting [39].

LuxaCrown is a new bis-acryl material, marketed as a 'semi-permanent' restoration that can last up to five years [39]. The manufacturer's claim is that LuxaCrown has flexural strength properties that can match or surpass those of permanent restorative materials like CAM/CAM fabricated feldspathic and hybrid ceramics [39]. Internally derived flexural strength data of LuxaCrown was compared with flexural strength data from a separate study on ceramic and hybrid ceramics; flexural strength testing of LuxaCrown and other ceramic materials were not done in the same experiment. The manufacturer also reported that fracture toughness increased over time and cyclic fatigue when compared to composite (Filtek Supreme Ultra) and hybrid ceramic (Vita Enamic) [39]. Currently there is no published data on the performance of LuxaCrown when compared to CADCAM milled provisional materials. Investigation of new materials mechanical strength properties are imperative to compare manufacturers' claims of strength and functional durability.

Provisional crowns may be used for prolonged periods of time, and their clinical performance is dependent on the mechanical strength properties [40]. It is imperative to understand the mechanical properties of the provisional restorations. Fracture strength data can be used to guide clinicians to select an appropriate material to meet the challenges of oral environment. It can also be used to predict the performance of provisionals when they are subjected under repeated masticatory forces in the oral cavity [19, 40]. A common cause of provisional failure is fracture during service [40, 41].[42,43] Mechanical strength is important in evaluating the clinical longevity of provisionals when subjected to masticatory forces [16].

The purpose of this study is to evaluate and compare the fracture strength and mode of fracture of CADCAM milled versus those that are directly fabricated from conventional, bis-acryl materials in a laboratory environment.

**HYPOTHESIS:**

Null Hypothesis**:** There is no difference in fracture strength between bis-acryl and CAD/CAM-fabricated provisional crowns after 24 hours of storage. There is no difference in modes of fabrications between chair-side (directly fabricated bis-acryl) and CAD/CAM (digitally designed and milled) provisional crowns after 24 hours in storage.

**METHODS AND MATERIALS:**

A Dentoform (Columbia Dentoform, NY, NY, USA) mandibular first molar tooth was prepared for a full ceramic crown with the following dimensions: 1.5 mm occlusal reduction, 1.0 mm axial reduction, and 1.0 mm round shoulder margin [11]. A polysiloxane index (Lab-Putty, Coltène/Whaledent AG, Altstätten, Switzerland) was fabricated to confirm reduction dimension and measured with a periodontal probe (UNC). Total occlusal convergence (TOC) was approximately 11 degrees [42]. An impression of a Dentoform molar tooth prior to crown preparation was be made using a sectional tray and vinyl-polysiloxane (Aquasil Ultra Heavy body and Aquasil XLV, Dentsply Caulk, Milford, DE, USA) and was utilized as a matrix for the fabrication of direct provisional crowns.

**Master die preparation:**

The prepared Dentoform tooth was embedded in a ISO Type 4 dental stone base (Die Stone, Kulzer, IN, USA) to the level of the CEJ. The stone housing was cylindrical in shape (14mm in diameter x 22 mm in height). An impression of the prepared Dentoform tooth and stone housing was made with vinyl-polysiloxane (PolyPour, GC America, Alsip, IL, USA) to fabricate a duplicate master die using DieStone for scanning using the CEREC Omnicam (Dentsply Sirona, York, PA, USA). A Standard Tesselation Language (STL) file was generated using the CEREC Premium software (Version 4.5, Dentsply Sirona, York, PA, USA). The SLT file was imported into Stereolithography technology software (SLA, Formlabs GmbH, Berlin, Germany) to fabricate dies a total of 40 dies using dental model resin Photopolymer Resin for Form 2 (FLDMBE02) with the following mechanical properties: Tensile Strength: 61MPa; Flexural Modulus:2.5 GPa (Figure 1) [43].

**Bis-acryl provisional crown fabrication:**

A provisional matrix was used to fabricate chairside crowns using Luxatemp Ultra (LT) and LuxaCrown (LC, DMG America, Ridgefield Park, NJ, USA). Ten provisional crowns were fabricated for each material. Adjacent teeth on the Dentoform were lubricated with petroleum jelly and the bis-acryl materials were mixed using an automixing gun, loaded into the matrix and seated on the prepared Dentoform tooth with finger pressure. Crowns were removed from the matrix in the elastic phase, excess trimmed with a plastic instrument and allowed to set in the matrix according to manufacturer's instructions. The oxygen inhibiting layer was removed with alcohol and 2x2 gauze before finishing and polishing with rotary rubber cups (Enhance, Dentsply LLC, Milford, DE, USA). All crowns were inspected under a microscope (Stereomicroscope S 300 II, G10XT, Kikuchi, Japan) for voids or defects. A digital caliper (General Tools, No. 1433, Secaucus, NJ, USA ) was used to confirm thickness and uniformity at buccal, lingual, mesial, distal and occlusal surfaces. Samples with voids, defects or insufficient thickness were discarded.

**CAD/CAM provisional crown fabrication:**

The CAD/CAM materials used were: Telio CAD (TC; PMMA, Ivoclar Vivadent, Schaan, Liechtenstein) and Vita CAD-temp (VC; acrylate polymer, Vita Zahnfabrik, Bad Säckingen, Germany). The prepared Dentoform tooth secured in its Typodont was scanned using CEREC Omnicam (Dentsply Sirona, York, PA, USA) and crowns designed on the CEREC Premium software (Version 4.5, Dentsply Sirona, York, PA, USA). Ten provisional crowns were milled from the design proposal with the same anatomy for for each material using a 4-axis milling unit (inLab MC XL, Dentsply Sirona, York, PA, USA).

The experimental set up was based on previous studies [7, 11, 41, 43, 44].

**Fracture strength test:**

Crowns were cemented to SLA dies using TempBond NE automix syringe (Kerr, Orange, CA, USA) according to manufacturer's instructions. Samples were randomized and stored in sterile water at room temperature for 24 hours, then dried with compressed air (Figure 2). All samples were subjected to a universal testing machine (MTS 858 Mini Bionix II test system, Eden Prairie, MN, Figure 3), with a plunger attachment 3.18 mm in diameter which applied a compression load at a crosshead speed of 1 mm/min to individual samples until failure. The maximum force at fracture was recorded. Failure type was classified according to Burke's classification [45] (Table 1).

**Statistical Analysis:**

A sample size of 10 for each brand/material type was based on the mean and standard deviation reported by Abdullah, et al [7, 11]. Fracture strength data was analyzed using a one-way ANOVA and Tukey post hoc test to evaluate differences in mean fracture strength among the four different materials. Nonparametric Wilcoxon rank sum tests were used to compare fracture patterns based on Burke's 4-category classification. The Wilcoxon p-value is based on the nonparametric Wilcoxon rank sum test. Chi-squared and

Fisher's exact test p-values were based on dichotomizing fracture pattern as minimal vs. > minimal. A significance level of 0.05 was utilized for all analyses.


Figure 1. a-c: Digital workflow to fabricate SLA (3-D printed) dies; d: SLA and Master dies.

Figure 2. Provisional crowns cemented to SLA fabricated dies.

| |
|---|
| Type I- Minimal fracture in crown |
| Type II- Less than half the crown |
| Type III- Crown fracture through midline, or half the crown displaced |
| Type IV- More the half the crown displaced |
| Type V- Severe fracture of the tooth and/or crown |

Table 1: Burke's classification of fracture pattern.

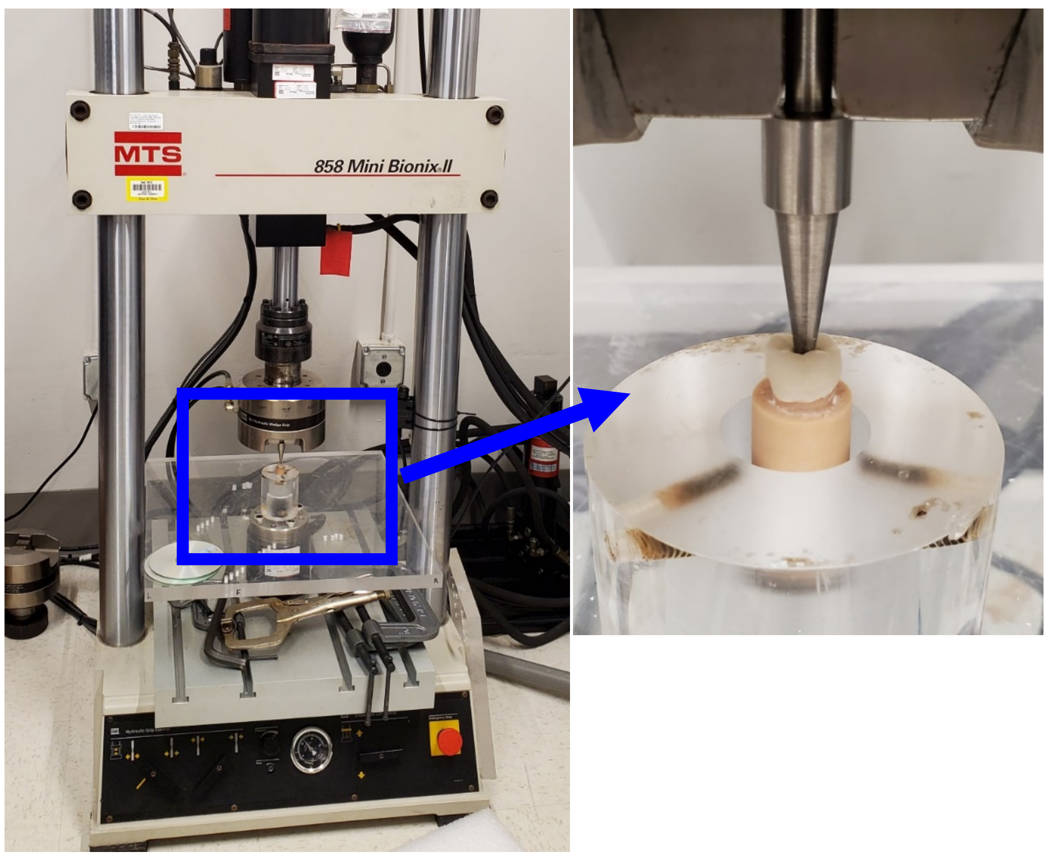


Figure 3. Specimen mounted on Universal Testing Machine.

**RESULTS:**

Maximum force at failure for each group (Mean ± SD, N) was 1547±443 for TC , 879± 194 for LC 747± 294 for VC, and 715 ± 159 for LT. One-way ANOVA with Tukey post hoc test showed that fracture strength for Telio CAD was significantly greater than all other materials (Figure 4, Table 2). No statistically significant differences were found among the other groups (Figure 3, Table 2). Bis-acryl materials were more likely to have minimal crown fracture than the CAD/CAM materials (75% vs. 40%, p=0.054; Figure 5-6, Table 3).

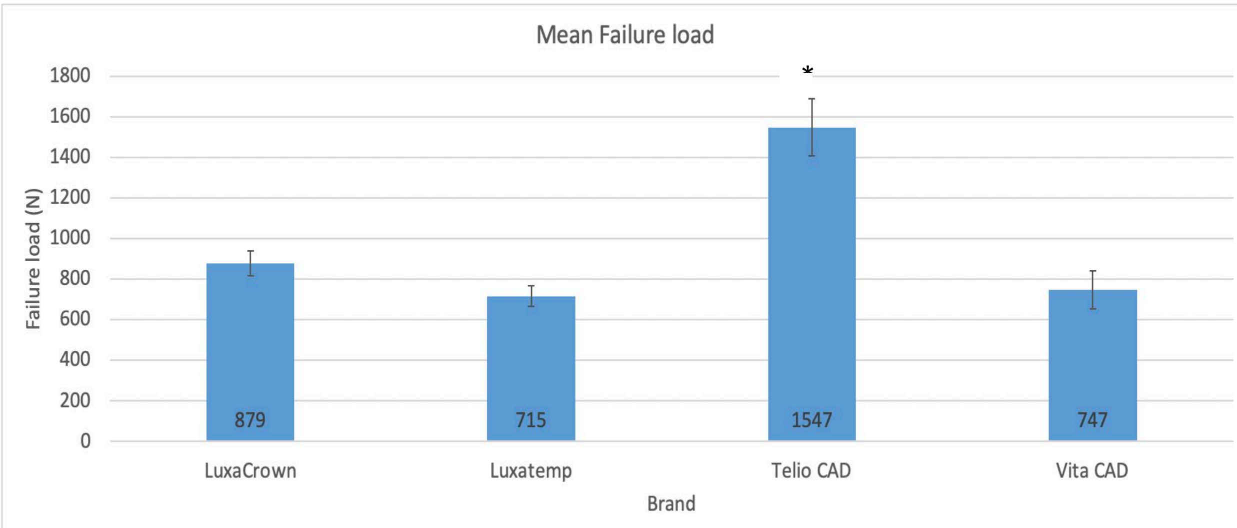


Figure 4: Fracture strength of provisional crowns. * indicates statistical significance value.

| Material | n | Mean | Std Dev | Coefficient of variation | Std Err | Median | Min | Max | |
|---|---|---|---|---|---|---|---|---|---|
| LuxaCrown | 10 | 879 | 194 | 22 | 62 | 943 | 482 | 1081 | |
| LuxaTemp | 10 | 715 | 159 | 22 | 50 | 706 | 497 | 981 | |
| Telio CAD | 10 | 1547 | 443 | 29 | 140 | 1538 | 528 | 2093 | |
| Vita CAD | 10 | 747 | 294 | 39 | 93 | 680 | 332 | 1366 | |
| Tukey post hoc tests p-values | | | | | | | | | |
| LuxaCrown vs. Luxatemp p>0.50 | | | | Luxatemp vs. Telio CAD p<0.001* | | | | | |
| LuxaCrown vs. Telio CAD p=.004* | | | | Luxatemp vs. Vita CAD p>0.50 | | | | | |
| LuxaCrown vs. Vita CAD p>0.50 | | | | Telio CAD vs. Vita CAD p<0.001* | | | | | |

Table 2. Overview of fracture strength of CAD/CAM and bis-acryl provisional crowns; * indicates statistical significance value.

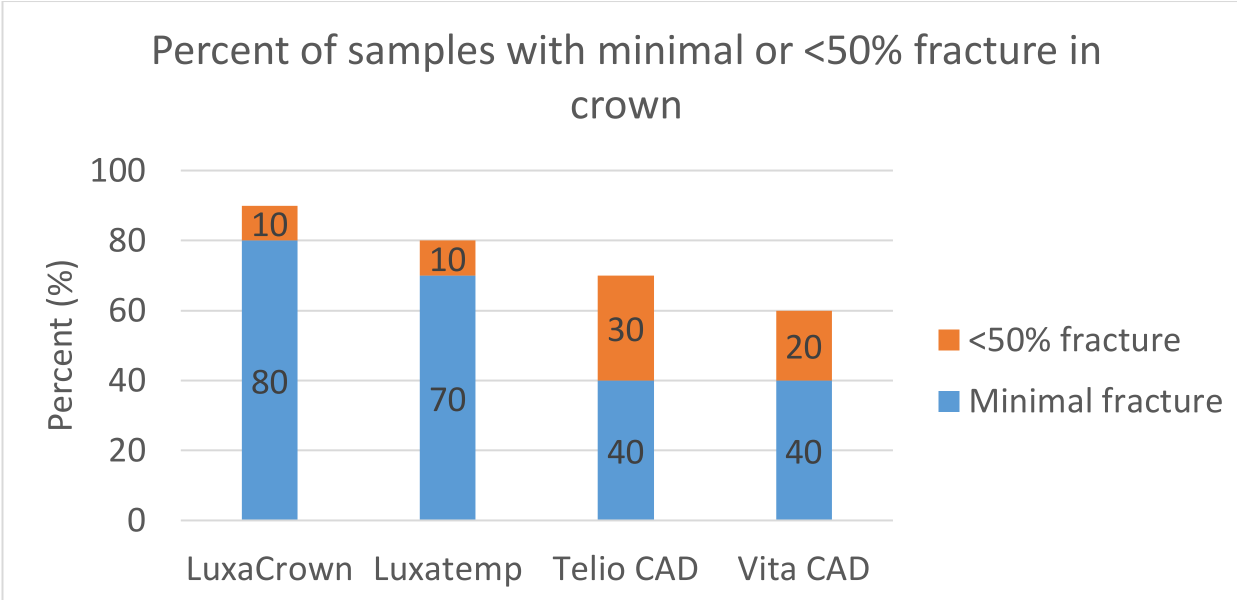


Figure 5. Percent of samples by material type with minimal or greater than minimal crown fracture.

Figure 6. Fracture patterns of all crown materials tested.

| | Fracture Pattern | | | | | |
|---|---|---|---|---|---|---|
| | Type I | | Type II-V | | p-value | |
| Material | n | % | n | % | Wilcoxon | Chi-square |
| LuxaCrown | 8 | 80 | 2 | 20 | 0.264 | 0.157 |
| Luxatemp | 7 | 70 | 3 | 30 | | |
| Telio CAD | 4 | 40 | 6 | 60 | | |
| Vita CAD | 4 | 40 | 6 | 60 | | |
| | | | | | | |
| Mode of Fabrication | n | % | n | % | Wilcoxon | Fisher's Exact Test* |
| Chair-side | 15 | 75 | 5 | 25 | 0.055 | 0.054 |
| CAD/CAM | 8 | 40 | 12 | 60 | | |

Table 3. Chi-square test and Fisher's exact test are based on dichotomizing as fracture Type I vs. >Type I.

## DISCUSSION:

This study evaluated the fracture strength and fracture patterns of provisional restorations made with contemporary bisacryl and CAD/CAM provisional materials, after 24-hour storage in sterile water. The null hypothesis was rejected as significantly different fracture strengths and patterns were found between materials.

Fracture strength is an important mechanical property for predicting clinical performance of provisional restorations [16, 40, 46]. To the author's knowledge there are limited studies evaluating the fracture strength of the materials included in this study in a single molar tooth in-vitro model. The results of this study showed that Telio CAD had the highest fracture strength value when compared to other materials in this study which may be explained by structural properties specific to this material. Telio CAD, industrially polymerized monolithic PMMA block has a molecular structure that is comprised of long, linear molecules with minimal intermolecular crosslinking that are highly dense, resulting in high strength [34]. Vita CAD Temp showed force to failure values that were not significantly different from the bis-acryl materials. Vita CAD is an acrylate polymer with vinyl groups that form polymers because of double bonds that are reactive which lowers strength, and has been shown to have lowest flexural strength before and after thermal cycling [34]. This may explain why fracture strength values were more comparable to the direct- method bis-acryl materials than CAD/CAM milled Telio CAD. Differences in filler composition affect mechanical properties, which could explain the difference between fracture strengths of both bis-acryls although these differences were not statistically significant [3, 47]. Previous studies evaluating CAD/CAM vs direct method provisionals in fixed partial dentures indicate that CAD/CAM PMMA had higher fracture strengths than direct method provisionals [16, 48, 49]. There were no significant differences observed in fracture strength between fabrication methods in this study, due to the relatively decreased fracture strength of Vita CAD when compared to Telio CAD.

Bisacryl materials tended to have minimal fractures (Type I) as compared to CAD CAM materials that had greater than 50% or more crown lost (Types II- III). This finding is inconsistent with previous studies by Reeponhama, et al and Abdullah , et al,[7, 44] which found that monomethacrylate samples showed Type I fracture patterns (less damage) than the bisacryl group, which were classified as Type II. Balkenhol, et al explained that monomethacryles display behavior of ductile material as it undergoes plastic deformation, whereas bis-acryls are brittle [50]. Other authors' have found that filler content plays an important role in stress distribution and strength [48] and fillers in PMMA materials promote crack deviation, which in turn increase the fracture toughness of the composite resin material in fixed partial dentures [26]. Ultimately, the different chemical compositions of each of the materials tested may have an impact on fracture strength [41].

Fracture strength values are highly variable depending on different factors to include modulus of elasticity of supporting die, cement properties, tooth preparation design and thickness of restoration [46]. The results in this study reflect force to fracture values that are much greater than other studies [7, 11]. This may be attributed to the low elastic modulus of the 3-D printed die model substrate which influenced the value of force to fracture of the crown material. A lower modulus of elasticity for the die material means that is was highly flexible and was able to deform more under a given load [43, 46]. Although all specimens were cemented by same operator, using finger pressure during cementation of the provisional, might have introduced variability that is reflected in the high variance in the data collected.

Future investigations in the subject of provisional crowns may include the effect of thermo-cycling and cyclic-fatigue on mechanical properties of these materials will better simulate the oral environment. The use of extracted teeth as substructure for fracture testing would allow for the more clinically relevant data in future studies.

## CONCLUSION:

Within the limitations of this study, fracture strength was significantly higher for TC compared to other materials. While failure load was lower for bis-acryl materials compared to TC, fracture pattern is often minimal. Failure load for LC tends to be higher than LT, but difference may not be clinically relevant. Fracture strength appears to be material dependent rather than on mode of fabrication. PMMA based CAD/CAM provisional material are better suited for long-span prosthesis, and long-term provisionals, whereas LuxaCrown may be appropriate for single unit crowns.

# REFERENCES


1. Ferro, K.J., et al., *The Glossary of Prosthodontic Terms.*
2. Sather, D.A., & Shillingburg, H. T. , *Fundamentals of Fixed Prosthodontics.* International Quintessence Publishing Group. , 2012. **Fourth edition**.
3. Takamizawa, T., et al., *Mechanical properties and simulated wear of provisional resin materials.* Operative dentistry, 2015. **40**(6): p. 603-613.
4. Shibasaki, S., et al., *Influence of different curing modes on polymerization behavior and mechanical properties of dual-cured provisional resins.* Operative dentistry, 2017. **42**(5): p. 526-536.
5. Ireland, M.F., et al., *In vitro mechanical property comparison of four resins used for fabrication of provisional fixed restorations.* The Journal of prosthetic dentistry, 1998. **80**(2): p. 158-162.
6. Hammond, B.D. and J.A. Hodd, *Fiber-reinforced interim fixed dental prostheses: A clinical protocol.* The Journal of prosthetic dentistry, 2016. **116**(4): p. 496-500.
7. Abdullah, A.O., S. Pollington, and Y. Liu, *Comparison between direct chairside and digitally fabricated temporary crowns.* Dental materials journal, 2018. **37**(6): p. 957-963.
8. Burns, D.R., D.A. Beck, and S.K. Nelson, *A review of selected dental literature on contemporary provisional fixed prosthodontic treatment: report of the Committee on Research in Fixed Prosthodontics of the Academy of Fixed Prosthodontics.* The Journal of prosthetic dentistry, 2003. **90**(5): p. 474-497.
9. Mehrpour, H., et al., *Evaluation of the flexural strength of interim restorative materials in fixed prosthodontics.* Journal of Dentistry, 2016. **17**(3): p. 201.
10. Givens Jr, E.J., et al., *Marginal adaptation and color stability of four provisional materials.* Journal of prosthodontics, 2008. **17**(2): p. 97-101.
11. Abdullah, A.O., E.A. Tsitrou, and S. Pollington, *Comparative in vitro evaluation of CAD/CAM vs conventional provisional crowns.* Journal of Applied Oral Science, 2016. **24**(3): p. 258-263.
12. Aschheim, K.W., *Esthetic Dentistry-E-Book: A Clinical Approach to Techniques and Materials*. 2014: Elsevier Health Sciences.
13. Güth, J., J.A. e Silva, and D. Edelhoff, *Enhancing the predictability of complex rehabilitation with a removable CAD/CAM-fabricated long-term provisional prosthesis: a clinical report.* The Journal of prosthetic dentistry, 2012. **107**(1): p. 1-6.
14. Anusavice, K.J., C. Shen, and H.R. Rawls, *Phillips' science of dental materials*. 2012: Elsevier Health Sciences.
15. Balkenhol, M., et al., *Provisional crown and fixed partial denture materials: mechanical properties and degree of conversion.* Dental Materials, 2007. **23**(12): p. 1574-1583.
16. Alt, V., et al., *Fracture strength of temporary fixed partial dentures: CAD/CAM versus directly fabricated restorations.* Dental materials, 2011. **27**(4): p. 339-347.
17. Young, H.M., C.T. Smith, and D. Morton, *Comparative in vitro evaluation of two provisional restorative materials.* The Journal of prosthetic dentistry, 2001. **85**(2): p. 129-132.

18. Gonçalves, F.P., et al., *Cytotoxicity evaluation of two bis-acryl composite resins using human gingival fibroblasts.* Brazilian dental journal, 2016. **27**(5): p. 492-496.
19. Astudillo-Rubio, D., et al., *Mechanical properties of provisional dental materials: A systematic review and meta-analysis.* PloS one, 2018. **13**(2): p. e0193162.
20. Nejatidanesh, F., G. Momeni, and O. Savabi, *Flexural strength of interim resin materials for fixed prosthodontics.* Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry, 2009. **18**(6): p. 507-511.
21. Savabi, O., et al., *Evaluation of hardness and wear resistance of interim restorative materials.* Dental research journal, 2013. **10**(2): p. 184.
22. Dayan, C., et al., *Wear resistance and microhardness of various interim fixed prosthesis materials.* Journal of oral science, 2019. **61**(3): p. 447-453.
23. Naik, B. and S. Mathur, *A Comparative Evaluation of Flexural Strength and Hardness of Different Provisional Fixed Restorative Resins With Varied Setting Reactions-An In Vitro Study.* National Journal of Integrated Research in Medicine, 2017. **8**(2).
24. Samuel, S.P., et al., *Mechanical properties of experimental dental composites containing a combination of mesoporous and nonporous spherical silica as fillers.* Dental Materials, 2009. **25**(3): p. 296-301.
25. Poonacha, V., et al., *In vitro comparison of flexural strength and elastic modulus of three provisional crown materials used in fixed prosthodontics.* Journal of clinical and experimental dentistry, 2013. **5**(5): p. e212.
26. Schwantz, J.K., et al., *Characterization of bis-acryl composite resins for provisional restorations.* Brazilian dental journal, 2017. **28**(3): p. 354-361.
27. Dureja, I., et al., *A comparative evaluation of vertical marginal fit of provisional crowns fabricated by computer-aided design/computer-aided manufacturing technique and direct (intraoral technique) and flexural strength of the materials: An in vitro study.* The Journal of the Indian Prosthodontic Society, 2018. **18**(4): p. 314.
28. Balkenhol, M., et al., *Effect of surface condition and storage time on the repairability of temporary crown and fixed partial denture materials.* Journal of dentistry, 2008. **36**(11): p. 861-872.
29. Kerby, R.E., et al., *Mechanical properties of urethane and bis-acryl interim resin materials.* The Journal of prosthetic dentistry, 2013. **110**(1): p. 21-28.
30. Thompson, G.A. and Q. Luo, *Contribution of postpolymerization conditioning and storage environments to the mechanical properties of three interim restorative materials.* The Journal of prosthetic dentistry, 2014. **112**(3): p. 638-648.
31. Singh, A. and S. Garg, *Comparative evaluation of flexural strength of provisional crown and bridge materials-an invitro study.* Journal of clinical and diagnostic research: JCDR, 2016. **10**(8): p. ZC72.
32. Khng, K.Y.K., et al., *In vitro evaluation of the marginal integrity of CAD/CAM interim crowns.* The Journal of prosthetic dentistry, 2016. **115**(5): p. 617-623.
33. Sari, T., et al., *Temporary materials: comparison of in vivo and in vitro performance.* Clinical Oral Investigations, 2020. **24**(11): p. 4061-4068.
34. Yao, J., et al., *Comparison of the flexural strength and marginal accuracy of traditional and CAD/CAM interim materials before and after thermal cycling.* The Journal of prosthetic dentistry, 2014. **112**(3): p. 649-657.

35. Peñate, L., et al., *Comparative study of interim materials for direct fixed dental prostheses and their fabrication with CAD/CAM technique.* The Journal of prosthetic dentistry, 2015. **114**(2): p. 248-253.
36. Peng, C.-C., K.-H. Chung, and H.-T. Yau, *Assessment of the internal fit and marginal integrity of interim crowns made by different manufacturing methods.* The Journal of prosthetic dentistry, 2020. **123**(3): p. 514-522.
37. Rayyan, M.M., et al., *Comparison of interim restorations fabricated by CAD/CAM with those fabricated manually.* The Journal of prosthetic dentistry, 2015. **114**(3): p. 414-419.
38. Hahnel, S., et al., *Performance of resin materials for temporary fixed denture prostheses.* Journal of oral science, 2019: p. 18-0150.
39. DMG, *Dental Materials for Practice, LuxaCrown*, in *LuxaCrown Brochure*. 2019/2020.
40. Yanikoğlu, N.D., et al., *Flexural strength of temporary restorative materials stored in different solutions.* Open Journal of Stomatology, 2014. **2014**.
41. Karaokutan, I., G. Sayin, and O. Kara, *In vitro study of fracture strength of provisional crown materials.* The journal of advanced prosthodontics, 2015. **7**(1): p. 27.
42. Yoon, S.S., et al., *Measurement of total occlusal convergence of 3 different tooth preparations in 4 different planes by dental students.* The Journal of prosthetic dentistry, 2014. **112**(2): p. 285-292.
43. Zimmermann, M., et al., *Fracture load of CAD/CAM-fabricated and 3D-printed composite crowns as a function of material thickness.* Clinical oral investigations, 2019. **23**(6): p. 2777-2784.
44. Reeponmaha, T., O. Angwaravong, and T. Angwarawong, *Comparison of fracture strength after thermo-mechanical aging between provisional crowns made with CAD/CAM and conventional method.* The Journal of Advanced Prosthodontics, 2020. **12**(4): p. 218.
45. Burke, F. and D. Watts, *Fracture resistance of teeth restored with dentin-bonded crowns.* Quintessence International, 1994. **25**(5).
46. Yucel, M.T., et al., *Influence of the supporting die structures on the fracture strength of all-ceramic materials.* Clinical oral investigations, 2012. **16**(4): p. 1105-1110.
47. Mei, M.L., et al., *Effect of heat treatment on the physical properties of provisional crowns during polymerization: an in vitro study.* Materials, 2015. **8**(4): p. 1766-1777.
48. Coelho, C., et al., *Comparison of CAD-CAM and traditional chairside processing of 4-unit interim prostheses with and without cantilevers: Mechanics, fracture behavior, and finite element analysis.* The Journal of Prosthetic Dentistry, 2021. **125**(3): p. 543. e1-543. e10.
49. Bauer, R., et al., *In vitro performance and fracture resistance of interim conventional or CAD-CAM implant-supported screw-or cement-retained anterior fixed partial dentures.* The Journal of Prosthetic Dentistry, 2020.
50. Balkenhol, M., et al., *Fracture toughness of cross-linked and non-cross-linked temporary crown and fixed partial denture materials.* dental materials, 2009. **25**(7): p. 917-928.