

---

**“COMPARATIVE EVALUATION OF SHEAR  
BOND STRENGTH OF MONOCRYSTALLINE  
AND POLYCRYSTALLINE CERAMIC BRACKETS  
USING TWO DIFFERENT BONDING SYSTEMS  
ON TWO DIFFERENT CAD/CAM MATERIALS :  
AN IN-VITRO STUDY”**

---

**By  
Dr. AKIN K KORATH  
REG. NO. II0219001**

*Dissertation*

*Submitted to  
KAHER, Belagavi, Karnataka  
In partial fulfilment of the requirements for the degree of*

**MASTERS OF DENTAL SURGERY  
IN  
ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS  
(BRANCH – V)**

**Under the Guidance of  
Dr. ROHAN HATTARKI M.D.S.**

**DEPARTMENT OF  
ORTHODONTICS AND DENTOFACIAL ORTHOPAEDICS  
KLE VISHWANATH KATTI INSTITUTE OF DENTAL SCIENCES,  
KAHER, BELAGAVI, KARNATAKA.**

---

**2019 – 2022**

---

KAHER, BELAGAVI

*Declaration by the Candidate*

I hereby declare that this dissertation/thesis entitled “**COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY**” is a bonafide and genuine research work carried out by me under the guidance of **Dr. ROHAN HATTARKI** M.D.S. Reader, Department of Orthodontics and Dentofacial Orthopaedics, KLE Academy Of Higher Education and Research, (KAHER) KLE V. K. Institute of Dental Sciences, Belagavi.

**Date :**

**Place:** Belagavi

**Dr. AKIN K KORATH**

**KAHER, BELAGAVI**

**Certificate by Guide**

This is to certify that the dissertation entitled “**COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY**” is a bonafide research work done by **Dr. AKIN K KORATH**, a postgraduate student in partial fulfilment of the requirement for the degree of Masters of Dental Surgery (MDS) in Orthodontics and Dentofacial Orthopaedics, (Branch V).

**Date :**

**Place:** Belagavi.

**Dr. ROHAN HATTARKI** M.D.S.

Reader

Department of Orthodontics &

Dentofacial Orthopaedics,

KLE Vishwanath Katti

Institute of Dental Sciences,

KAHER, Belagavi-590010.

KAHER, BELAGAVI

*Endorsement by the Head of the Department  
and Principal/Head of the Institution*

This is to certify that the dissertation entitled “**COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY**” is a bonafide research work done by **Dr. AKIN K KORATH**, a postgraduate student under the guidance of **Dr. ROHAN HATTARKI** M.D.S. Reader, Department of Orthodontics and Dentofacial Orthopaedics, KLE Academy Of Higher Education and Research, (KAHER) KLE V. K. Institute of Dental Sciences, Belagavi.

**Head of Department**

**Dr. Tejashri Pradhan** M. D.S.  
Professor & Head,  
Department of Orthodontics and  
Dentofacial Orthopaedics,  
KLE Vishwanath Katti  
Institute of Dental Sciences,  
KAHER, Belagavi.

**Date :**  
**Place:** Belagavi

**Principal**

**Dr. Alka Kale** M. D.S.  
Principal,  
KLE Vishwanath Katti  
Institute of Dental Sciences,  
KAHER, Belagavi.

**Date :**  
**Place:** Belagavi

KAHER, BELAGAVI

Copyright  
Declaration by the candidate

I hereby declare that the KAHER, Belagavi, Karnataka shall have the rights to preserve, use & disseminate this Dissertation/Thesis entitled “**COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY**” in print or electronic format for Academic/Research Purposes.

**Date :**

**Dr. AKIN K KORATH**

**Place:** Belagavi.

**© KAHER, Belagavi Karnataka**

[Established under section 3 of the UGC Act, 1956 vide GOI. Notification  
No. F.9-19/2000- U.3 (A)]

## UNDERTAKING

I, **Dr. AKIN K KORATH** Post-Graduate student in the subject of Orthodontics and Dentofacial Orthopaedics, have completed research work on the topic **“COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY”**, in the year 2021.

I have been given to understand that any research work I undertake for dissertation, oral presentation or publication during my study course shall be the property of the KLE Academy of Higher Education and Research, (KAHER) KLE V. K. Institute of Dental Sciences, Belagavi. Hence, I hereby declare that the name of the Department, Institute and University shall be mentioned in my publications. The authorship shall be according to the guideline informed to me.

**Signature of the Post-Graduate Student**

## UNDERTAKING

I, **Dr. AKIN K KORATH** hereby declare that the information and data mentioned in my thesis entitled “**COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY**” belongs to me and is original.

I am aware of the definition of plagiarism as detailed below:

- An act or instance of using or closely imitating the language and thoughts of another author without authorization and the representation of that author’s work as one’s own, as by not crediting the original author.
- A piece of writing or other work reflecting such unauthorized use or imitation.
- The deliberate or reckless representation of another’s words, thoughts or ideas as one’s own without attribution in connection with the submission of academic work, whether graded or otherwise.



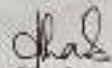
I hereby declare that the thesis prepared by me is an original one and does not involve plagiarism anywhere. In case at a later stage, it is found that I have indulged in plagiarism, then I am solely responsible for the same and the Institution is at liberty to take any disciplinary action against me including cancellation of dissertation or any other penalties imposed by the University.

Place:

Date:

Signature of Student

# PLAGIARISM ACCEPTED LETTER

<b>Scientific Correspondence and Review Committee</b>	
<b>KLE VK Institute of Dental Sciences</b>	
	<b>A Constituent Unit of KLE Academy of Higher Education and Research (Deemed-to-be-University u/s 3 of the UGC Act, 1956)</b> Nehru Nagar, Belagavi - 590 010, Karnataka State Accredited 'A' Grade by NAAC (2nd Cycle)
☎: 0831-2470362 FAX: 0831-2470640	Placed in Category 'A' by MHRD (GoI) Web: <a href="http://www.kledental-bgm.edu.in">http://www.kledental-bgm.edu.in</a> E-mail: <a href="mailto:principal@kledental-bgm.edu.in">principal@kledental-bgm.edu.in</a>
Date : 28.11.2021	Serial No. : 066
<b>PLAGIARISM CHECK REPORT</b>	
Name of the Applicant : Dr. Akin Korath UG / PG / Ph.D / Staff : POST GRADUATE Batch & Year : 2019-2022 Department : ORTHODONTICS AND DENTOFACIAL ORTHOPAEDIC	
The soft copy of <u>Research Work / Manuscript</u> by <u>DR. AKIN KORATH</u> entitled " <u>COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF</u> <u>MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS</u> <u>USING DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD-</u> <u>CAM MATERIALS.</u> under the guidance of <u>DR. ROHAN HATTARU</u> has been submitted for Anti-Plagiarism check to the Scientific Correspondence & Review Committee of KLE VK Institute of Dental Sciences using "Turn-it-in" software.	
The scan has been carried out and the scanned output reveals a Similarity Index of <u>7</u> %, which is <u>within</u> / <del>not within</del> the acceptable limits of 10% as per the UGC guidelines.	
 <b>Member Secretary</b> Scientific Correspondence and Review Committee KLEVK Institute of Dental Sciences KAHER-Belagavi	 <b>Chairman</b> Scientific Correspondence and Review Committee KLEVK Institute of Dental Sciences KAHER - Belagavi

## BIostatISTICS CLEARANCE CERTIFICATE



### **KLE V.K. Institute of Dental Sciences**



(A Constituent Unit of KLE Academy of Higher Education & Research  
Deemed-to-be-University, U/S 3 of the UGC Act, 1956)  
Kefir, Nagar, Belagavi-590 010 INDIA

Re-Accredited 'A' grade by NAAC (2<sup>nd</sup> Cycle) & Placed in Category 'A' by MHRD (GoT)

Tel: 0831-2470362  
Fax: 0831-2470340

Web: <http://www.kle.ac.in>  
E-mail: [enquiry@kledental.kap.ac.in](mailto:enquiry@kledental.kap.ac.in)

## Biostatistics Clearance Certificate

This is to certify that the Biostatistics aspect of the Dissertation / Research work of **Dr. AKIN K KORATH** entitled "**COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF MONOCRYSTALLINE AND POLYCRYSTALLINE CERAMIC BRACKETS USING TWO DIFFERENT BONDING SYSTEMS ON TWO DIFFERENT CAD/CAM MATERIALS : AN IN-VITRO STUDY**" has been done under my guidance and considered satisfactory.

Place : Belagavi

Name & Signature of Biostatistician

Date :

## Acknowledgement

First and foremost, I would like to thank God Almighty for giving me the strength, knowledge, ability and opportunity to undertake this research study and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

In my journey towards this degree, I have found a teacher, a friend, an inspiration, a role model and a pillar of support in my Guide, **Dr. Rohan Hattarki MDS, Reader**, Department of Orthodontics and Dentofacial Orthopaedics, KLE Academy of Higher Education and Research, (KAHER) KLE V. K. Institute of Dental Sciences, Belagavi. He has provided his heartfelt support to me at all times and has given me invaluable guidance, inspiration and suggestions in my quest for knowledge. He has given me all the freedom to pursue my research, while silently and non-obtrusively ensuring that I stay on course and do not deviate from the core of my research. I gratefully acknowledge the pertinent criticism, pragmatic suggestions and advice given to me through my time as a postgraduate student. His passion for the subject, vast knowledge, calm and composed nature and skill are all standards I hope to breach someday. Without his able guidance, I would not be where I am today, and I shall eternally be grateful to him for his assistance.

I am highly obliged to **Dr. Alka Kale MDS, Principal, Dr. Anjana Bagewadi Vice-principal**, KAHER's KLE Vishwanath Katti Institute of Dental Sciences, KLE University, Belagavi, for providing the academic support and letting me avail facilities and infrastructure of the institution.

I have great pleasure in acknowledging my gratitude to my respected teachers **Dr. Tejashri Pradhan** MDS Professor and Head, **Dr. K M Keluskar** MDS, PHD Professor, **Dr. Roopa Jatti** MDS Professor, **Dr. Anand Badavannavar** MDS Reader, **Dr. Amit Nilgar** MDS Reader, **Dr. Trupti Sadhunavar** MDS Lecturer, **Dr. Devyani Desai** MDS Lecturer, **Dr. Adithi** MDS Lecturer and **Dr. Pravin Mandaki** MDS Lecturer, of Department of Orthodontics and Dentofacial Orthopaedics for their constant guidance and above all their inspirational support at all times.

I sincerely thank all my postgraduate colleagues **Dr. Preethi**, **Dr. Charles**, **Dr. Sanjyot**, **Dr. Deepa** and **Dr. Pranani** for the modest help, words of encouragement and confidence that kept me motivated. I thank them for reinsuring me, that the fire keeps burning and for being there at times when I required them the most. They propelled me on the course of not only my thesis but also through the three years of my post-graduation. Their support, encouragement and credible ideas have been great contributors to the completion of my thesis.

Special heartfelt thanks to my seniors, **Dr. Fifi** and **Dr. Ann** for always being there for me no matter what in unexplainable ways through the ups and downs of these three years, constantly motivating and supporting me.

I take this opportunity to show my gratitude to all my seniors- **Dr. Susmita**, **Dr. Yatin**, **Dr. Pooja**, **Dr. Poojith**, **Dr. Aarti**, and my juniors- **Dr. Riddhi**, **Dr. Namit**, **Dr. Tanvi**, **Dr. Shreya**, **Dr. Aravind**, and **Dr. Sagar** for their constant support and motivation that helped me do my work with maximum enthusiasm.

It would be inappropriate if I omit to mention the name of my closest friend **Dr. Theres**, who has been there for me through all my ups and downs. I would like to

thank her for being the core of my support system, a pillar of strength, especially at times when I needed it the most.

I acknowledge all my friends and well-wishers, whom I have not mentioned above for their cooperation and support whenever needed.

I am very much indebted to this department and extend my appreciation to all the non-teaching staff of the department for their able assistance.

I would like to thank **Dr. Sathiya Priya** for helping me with the statistics involved in my thesis.

I would like to acknowledge the work of **Mr. Arun and Mr. Anand, Library Xerox Centre**, for the excellent formatting, printing and binding of my thesis.

My acknowledgement would be incomplete without thanking the biggest source of my strength- my Family. The blessings of my grandparents, late **Mrs. Jolly Abraham** and **Mr. K Abraham**, **Mrs. Mini Thampi** and **Dr. Thampi Vargheese**, my parents **Mrs. Neetha Korath** and **Dr. Korath Abraham**, and the love and care of my younger brother, **Mr. Joel Korath** who has unconditionally supported me and made a tremendous contribution in helping me reach this stage in my life. I thank them for putting up with me in difficult moments persuading me to follow my dream of getting this degree. This would not have been possible without their unwavering and unselfish love and support given to me at all times. They are my confidantes, without whom umpteen things would never have materialized. Thank you for all that you have done, through all these years. Thank you for being the core of my support system, a pillar of strength to me, especially at times when I needed it the most. I

present this thesis as an unassertive tribute to all their love, affection, dreams and strong principles, which they have instilled in me.

Thank you one and all.

**Dr. AKIN K KORATH**

## **LIST OF ABBREVIATIONS**

SBS	-	Shear Bond Strength
LU	-	Lava Ultimate
VE	-	Vita Enamic
MPa	-	Megapascal
HFA	-	Hydrofluoric Acid
CAD/CAM	-	Computer-aided Design and Computer-aided Manufacturing

## ABSTRACT

**Introduction:** Adult patients seeking orthodontic treatment have increased significantly in the last decade. In spite of the emergence of Invisalign, a large group of adult patients still favor ceramic brackets as choice for esthetic orthodontic treatment. With the increase in age, patients may require certain crowns and dental restorations in addition to orthodontic therapy. With the emergence of CAD/CAM in dentistry, single tooth crown restorations may now be made both chairside and in the lab. So, it has become very important for orthodontist to find a proper bonding protocol which gives optimal bond strength to bond metal and ceramic brackets to the newer CAD/CAM materials. The aim of the study was to evaluate the SBS of monocrystalline and polycrystalline ceramic brackets on different CAD/CAM materials using two different bonding agents.

**Materials and methods:** In the present study we have evaluated the SBS of monocrystalline and polycrystalline ceramic brackets on LU and VE CAD/CAM blocks using Transbond XT and Universal single bond bonding agents. Based on the type of ceramic brackets and primer used, forty ceramic samples from each CAD/CAM group were categorized into four subgroups of 10 samples each. SBS were tested using Universal testing machine followed by assessment of Adhesive Remnant Index using Stereomicroscope based on Olsen and Bishara scores. The statistical analysis was done using Windows SPSS VERSION 25.0. The Independent t – test was used to compare between the two study groups. The statistical significance was kept at p – value less than 0.05.

**Results:** The SBS of polycrystalline bracket bonded on LU material using Transbond XT bonding agent was 16.37±2.43MPa. Whereas the SBS, when it was bonded using universal bonding agent was 15.84±4.22MPa. The SBS of monocrystalline bracket bonded on LU material using Transbond XT bonding agent was 12.530±3.30Mpa. Whereas the SBS, when it was bonded using universal bonding agent was 14.30±2.76MPa. The SBS of polycrystalline bracket bonded on VE material using Transbond XT bonding agent was 17.98±5.61MPa. Whereas the SBS, when it was bonded using universal bonding agent was 16.911±6.88MPa. The SBS of monocrystalline bracket bonded on VE material using Transbond XT bonding agent was 7.92±1.89MPa. Whereas the SBS, when it was bonded using universal bonding agent was 13.090±1.89MPa. A statistically significant difference was seen when evaluating the shear bond strength between different ceramic brackets and CAD/CAM materials ( $p < 0.05$ ).

**Conclusion:** Based on the recorded data and findings with the statistical analysis the type of ceramic brackets and CAD/CAM material had an impact on shear bond strength. Polycrystalline brackets had higher bond strength than monocrystalline brackets and the type of bonding agent used did not have a significant impact on shear bond strength. All the groups have shown shear bond strength exceeding the recommended range, so additional use of silane coupling agent is not required as it may degrade and damage CAD/CAM surfaces during debonding procedure.

**Keywords** : Shear bond strength, TransbondXT, Universal Single bond, Polycrystalline brackets, Monocrystalline brackets, CAD/CAM materials

## CONTENTS

<b>SL NO.</b>	<b>PARTICULARS</b>	<b>PAGE NO.</b>
<b>1.</b>	<b>INTRODUCTION</b>	<b>1-4</b>
<b>2.</b>	<b>AIM AND OBJECTIVES</b>	<b>5</b>
<b>3.</b>	<b>REVIEW OF LITERATURE</b>	<b>6-13</b>
<b>4.</b>	<b>METHODOLOGY</b>	<b>14-24</b>
<b>5.</b>	<b>RESULTS</b>	<b>25-32</b>
<b>6.</b>	<b>DISCUSSION</b>	<b>33-38</b>
<b>7.</b>	<b>CONCLUSION</b>	<b>39</b>
<b>8.</b>	<b>SUMMARY</b>	<b>40</b>
<b>9.</b>	<b>BIBLIOGRAPHY</b>	<b>41-45</b>
<b>10.</b>	<b>ANNEXURES</b>	<b>46-50</b>

## LIST OF TABLES

<b>TABLE NO.</b>	<b>PARTICULARS</b>	<b>PAGE NO.</b>
<b>1.</b>	Comparison of shear bond strength between the Transbond XT and universal bonding agents	<b>27</b>
<b>2.</b>	Comparison of shear bond strength between the polycrystalline and monocrystalline brackets	<b>28</b>
<b>3.</b>	Comparison of shear bond strength between the LU and VE CAD-CAM materials	<b>29</b>
<b>4.</b>	Distribution of Adhesive Remnant Index (ARI) Scores Among the Groups	<b>30</b>

## LIST OF GRAPHS

<b>GRAPH NO.</b>	<b>PARTICULARS</b>	<b>PAGE NO.</b>
<b>1.</b>	Comparison of shear bond strength between the Transbond XT and universal bonding agents	<b>31</b>
<b>2.</b>	Comparison of shear bond strength between the polycrystalline and monocrystalline brackets	<b>31</b>
<b>3.</b>	Comparison of shear bond strength between the LU and VE CAD-CAM materials	<b>32</b>

## LIST OF ANNEXURES

<b>ANNEXURE NO.</b>	<b>PARTICULARS</b>	<b>PAGE NO.</b>
<b>I</b>	Ethical clearance	<b>46</b>
<b>II</b>	Master Chart	<b>47-50</b>

## **INTRODUCTION**

Facial aesthetics is an important aspect of dentistry, including adult orthodontics<sup>1,2</sup>. With the increase in age, patients may require certain crowns and dental restorations in addition to orthodontic therapy<sup>3</sup>.

Dental ceramics are becoming more popular as a material for creating natural-looking restorations that can replace damaged or missing anterior teeth<sup>4</sup>.

In contemporary fixed prosthodontics, “dental ceramics” remains the best restorative material when it comes to biocompatibility and aesthetic properties<sup>3</sup>.

With the emergence of “Computer-aided design and Computer-aided manufacturing (CAD/CAM)” in dentistry, single tooth crown restorations may now be made both chairside and in the lab. The crowns are made from translucent ceramic blocks that have been machined.

The newer materials are attractive and durable; the laboratory processing is more efficient; the restoration fabrication is faster; and greater quality control of restorations such as fit, mechanical durability, and predictability are all advantages of using “CAD/CAM” in dentistry. These will benefit the patients in the long run<sup>5</sup>.

The frequency of malocclusion in people in the United States is roughly 50%, according to the “NHANES III” database. Malocclusion affects 40 % to 76% of people in Western Europe. According to an earlier study, the occurrence of malocclusion in adults is comparable to or greater than that of adolescents and children. Adult patients seeking “orthodontic treatment” have increased significantly in the last decade. Therefore a dependable method for “bonding” brackets to dental

restorations has become necessary<sup>4</sup>. Difficulties related to bonding performance are seen in adult orthodontic cases when orthodontic brackets are bonded to various “restorations” utilized for “crown or laminate restorations”, such as ceramics or new generation “CAD/CAM” materials<sup>6-9</sup>. Different surface treatment procedures have been described in the dental literature to increase “shear bond strength” (SBS) between brackets and dental restorative materials, particularly “dental ceramics”<sup>3</sup>.

According to Reynolds, the ideal bonding strength between an orthodontic bracket and porcelain is “6–8 MPa”<sup>10</sup>. The idea that increased “SBS” leads to better “orthodontic therapy” is questionable, because increased “SBS” might degrade “restorative surfaces” while debonding<sup>11</sup>. This means that the “SBS” between brackets to “dental materials or tooth surfaces” must be sufficiently high for better “orthodontic therapy” while low enough to avoid microscopic cracks to “bonding surfaces” during the “debonding procedure”. “Thurmond et al. discovered that bond strengths of more than 13 MPa between ceramic and adhesive bonding can produce fracture to ceramic restorative material<sup>12</sup>”.

Sarac et al, evaluated if “air particle abrasion and tribochemical silica coating” affected the “SBS” of “feldspathic, leucite reinforced, and fluorapatite dental ceramics” to brackets. They found that “chair-side tribochemical silica coating” enhanced the “SBS” values in all groups<sup>13</sup>.

Alumina sandblasting, “hydrofluoric acid (HFA)”, “silane”, and silica-coating treatments were used to test the SBS of “feldspathic dental porcelain” to brackets in a previous research paper. In the outcome of the investigation, all the methods showed SBS within the optimal range for clinical use<sup>4</sup>.

The bond strength of “ceramic brackets” to “CAD/CAM” material was sufficient after surface preparation procedures such as sandblasting and hydrofluoric acid application. Buyuk et al, showed that “TransbondXT” adhesive primer had stronger SBS than “Clearfill” ceramic primer when used after acid etching<sup>14</sup>.

But in a clinical situation sandblasting cannot be done due to its destructive nature. “HFA” may cause injury to “soft tissues and damage dental structures”; therefore, proper care must be given during their use<sup>15</sup>.

Buyuk et al, in their article assessed the “SBS” of “stainless steel brackets” to different “CAD/CAM” materials have concluded that SBS can change according to different “CAD/CAM” materials and type of bonding agents used<sup>14</sup>.

The essential characteristics of an ideal orthodontic appliance are good aesthetics and optimal technical performance. As the number of adult patients has increased, various aesthetically better appliances have been developed. “Ceramic brackets” were first used in orthodontics in 1986 and have since become an essential part of the orthodontist's armamentarium. Product design and clinical performance have considerably improved since their introduction<sup>16</sup>.

Ozarsla et al, evaluated the bond strength of “ceramic brackets” to “CAD/CAM materials” after different “surface treatments” have concluded that sandblasting and “HFA application” resulted in insufficient “bond strength” to “ceramic brackets” in both “CAD/CAM” materials<sup>3</sup>.

The two types of “ceramic brackets” that are available are “monocrystalline and polycrystalline”.

The main benefit of manufacturing from a single crystal is the elimination of any stress-inducing impurities or flaws. The main disadvantages of making “monocrystalline” brackets are the difficulty and additional cost of milling<sup>12</sup>.

The main advantage of manufacturing “polycrystalline” brackets is the capability to mould brackets, which is a very inexpensive procedure that produces vast quantities. The main disadvantages of this moulding method are structural defects at grain boundaries and trace levels of contaminants. Under stress, small amounts of contaminants as little as .001 percent or minor defects can act as foci for fracture propagation. Making “polycrystalline brackets” by injection moulding is an alternate option. Brackets do not need to be machined in this procedure; therefore structural flaws caused by the cutting process are avoided.

Fused “aluminium oxide” with grain boundaries created by the moulding process and heat treatment refracts light, giving it opacity. The optical clarity of “polycrystalline and single-crystal brackets” is the most noticeable difference<sup>16</sup>.

It has been found out that the SBS of “polycrystalline brackets” is higher than that of “monocrystalline” in an in-vitro study by Viazis et al, in extracted premolar tooth. To date there has been no study to see if it is true when they are bonded to “CAD/CAM” materials<sup>17</sup>.

Thus, this research sought to access the “bond strength” of “monocrystalline and polycrystalline ceramic brackets” on two “CAD/CAM materials” using two different bonding agents.

## **AIM AND OBJECTIVES**

### **AIM**

To access the “shear bond strength” of “monocrystalline and polycrystalline ceramic brackets” on different “CAD/CAM” materials using two different bonding systems.

### **OBJECTIVES**

- (1) To access the “shear bond strength” of “monocrystalline and polycrystalline ceramic brackets” bonded on “Vita Enamic” “CAD/CAM” material using “Transbond XT” bond with light cure gun.
- (2) To access the “shear bond strength” of “monocrystalline and polycrystalline ceramic brackets” bonded on “Vita Enamic” “CAD/CAM” material using Universal bond with light cure gun.
- (3) To access the “shear bond strength” of “monocrystalline and polycrystalline ceramic brackets” bonded on “Lava Ultimate” “CAD/CAM” material using “Transbond XT” bond with light cure gun.
- (4) To access the “shear bond strength” of “monocrystalline and polycrystalline ceramic brackets” bonded on “Lava Ultimate” “CAD/CAM” material using Universal bond with light cure gun.

## **REVIEW OF LITERATURE**

- **Petra Schmage, Ibrahim Nergiz, Wolfram Herrmann, and Mutlu Ozcan** (“AJODO 2003”)<sup>18</sup> investigated if there is a difference in “surface roughness” of the porcelain when different “surface conditioning” techniques are used and to assess whether these techniques alone or combination with “silane” affected bond strengths when metal brackets were bonded to the porcelain surfaces. They concluded that :

1. Surface roughness was more in diamond bur and “alumina oxide” sandblasting groups compared to “Hydrofluoric acid” etching or silicization. “Hydrofluoric acid etching” and “silica coating” should be the recommended methods for surface roughness.
2. The use of “silane” in conjunction with “Hydrofluoric acid etching” did not significantly improve the “bond strength”, but it did improve in the “sandblasting group”.
3. “Silica coating” in conjunction with “silanation” might have the capability to replace other techniques.

- **Theodore Eliades, Anthony D. Viazis, and George Eliades**<sup>19</sup> ( “AJODO 1991”) evaluated the microstructure and form to assess the interracial surface shapes and “SBS” of three different types of “ceramic brackets” bonded using “light-cured and self-cure composites”. They concluded that :

1. “Gamma-methacryloxypropyltrimethoxysilane” was the “silane” layer covering the bases of all “ceramic brackets”.

2. The pattern of the bracket base had an impact on the thickness of the composite layer.
3. “ceramic brackets” which had micromechanical retention along with “silane” layer coated bracket base had the highest bond strength.
4. Adhesive systems did not play a role in shear bond strength.

• **Vittorio Cacciafesta, Paul-Georg Jost-Brinkmann, Uwe Subenberger, and Rainer-Reginald Miethke (“AJODO 1998”)<sup>20</sup>** assessed the “SBS” when “stainless steel” and “ceramic brackets” were bonded to enamel under various surface conditions using light-cured glass ionomer cement. They concluded that :

1. Bond strength obtained in this study suggests that “Fuji Ortho LC” can be used for bonding in clinical practice.
2. In a dry field of operation when metal and “ceramic brackets” were bonded to unconditioned enamel surface using “Fuji Ortho LC” acceptable shear bond strengths were observed.
3. Clinically adequate bond strengths were obtained even when both brackets were bonded to water-contaminated unconditioned enamel surfaces with “Fuji Ortho LC”.

• **“Elham S. J and Ahed M. S. Al-Wahadni” (“EOS 2007”)<sup>21</sup>** evaluated the “SBS” when “metal brackets” were bonded to “CAD/CAM porcelain surfaces” and also assessed the difference in “shear bond strength” between “CAD/CAM” porcelain surfaces with each other and with “metal-ceramic” . They concluded :

1. Adequate “shear bond strength” for “orthodontic attachments” was observed in every groups.

2. The least “SBS” was observed in “IPS-empres”.

- **Ladan Eslamian, Ali Borzabadi-Farahani, Nasim Mousavi, and Amir Ghasemi (“EOS 2012”)**<sup>22</sup> evaluated if various surface treatments of resin composite restorations had an effect on “SBS” when “ceramic brackets” were bonded to treated surfaces. They found that :

1. The greatest “shear bond strength” was seen in the “diamond bur and alumina oxide” sandblasting group. “Hydrofluoric acid” - treated groups had the least bond strength.

2. Significant variations in adhesive remanent index scores were seen between the surface treatment groups.

3. “ceramic brackets” had significantly higher bond strength compared to stainless steel brackets.

- **Selma Elekdag-Turk, Y. Sinasi Sarac ,Tamer Turk and Duygu Sarac (“EOS 2007”)**<sup>23</sup> assessed if various curing modes and curing time of an “LED” unit have an effect on “SBS” when “ceramic brackets” were bonded to “ceramic surfaces”. They concluded :

1. “Quatz-tungsten-halogen and LED” units had similar shear bond strength.

2. No composite resin was seen on any ceramic facets. 50% of specimens in each group showed porcelain damage.

3. “LED” with a 3-second curing time provides good bond strength.

- **Marc E. Olsen, Samir E. Bishara, Daniel B. Boyer, and Jane R. Jakobsen (“AJODO” 1996)<sup>24</sup>** assessed the influence of various etching time on the “shear bond strengths” of “ceramic brackets”. They concluded that even when the etch time was reduced to 10 seconds a clinically acceptable bond strength was observed.
  
- **Saadet Saglam Atsua, Ibrahim Erhan Gelgorb, and Volkan Sahinc (“AO 2006”)<sup>25</sup>** investigated the “bond strength” of “stainless steel and alumina brackets” bonded to enamel surfaces conditioned with “tribochemical silica and “silane” coating” using “light-cured adhesive”. They found that “shear bond strength” values of the “stainless steel and the alumina brackets” to “enamel” have increased after using “tribochemical silica”-coating systems.
  
- **Elham S. J, Issam A. Abu and M. S. AlWahadni (“EOS 2010”)<sup>26</sup>** evaluated the bond strength of stainless steel and alumina brackets bonded to “IPS Empress 2 and In-Ceram Alumina” using two different etchants. They concluded that :
  1. Different ceramic materials didn't affect shear bond strength.
  2. Type of etchants had a significant impact on shear bond strength
  
- **Y G Reddy, Rohit Sharma, Ammandeep Singh, Vishal Agrawal, Vijay Agrawal, and Saurab Chaturvedi (“JCRD 2013”)<sup>27</sup>** compared the “shear bond strength” of “ceramic brackets and metal brackets”. They concluded that “alumina brackets” had higher “shear bond strength” than “metal brackets”.

- **Behnam Mirzakouchaki, Soodabeh Kimyai, Mahboubeh Hydari, Shirin Shahrbafe, and Parvin Mirzakouchaki-Boroujeni (“Med Oral Patol Oral Cir Bucal. 2012”)**<sup>28</sup> assessed if bonding technique had an effect on bond strength and failure sites with regard to metallic and “ceramic brackets”. They concluded that :

1. Metallic brackets showed significantly higher “bond strength” compared to “ceramic brackets” and the total-etch bonding technique was superior to self-etching primer in terms of “bond strength”.
2. “Bond strength” and failure sites had a positive correlation.

- **Gursimrit K. Grewal, Y. Torrealbab, and M. O. Lagravere (“AO 2014”)**<sup>29</sup> did a systematic review in which they determined which materials and technique/protocol showed the best results in bonding “brackets to ceramic surfaces”. They found that using “9.6% hydrofluoric acid to etch for 1 minute, then rinsing for 30 seconds followed by air-drying”.

- **Buncha Samruajbenjakula and Boonlert Kukiattrakoonb (“AO 2009”)**<sup>30</sup> evaluated the impact of base designs of “ceramic brackets” on “shear bond strength” when bonded to “glazed feldspathic porcelains”, and evaluated the adhesive remanent score after bond failure. They concluded that :

1. “Ceramic brackets” with bead base design bonded to “glazed feldspathic porcelains” had the highest shear bond strength values among all groups.
2. The bond strength values obtained in all the groups were more than the minimum orthodontic bond strength.
3. Porcelain surfaces damage was not seen during the debonding procedure.

- **Boyd O. Whitlock III, David Eick, Richard J. Ackerman, Alan G. Glaros, and Robed P. Chappell (“AJODO 1994”)<sup>31</sup>** assessed if porcelain priming agent had an impact on the shear bond strength when used along with the adhesive to bond “ceramic brackets” to dental porcelain and to observe if any fractures are present on porcelain surfaces after bond failure. They concluded that

1. A significantly higher “shear bond strength” was seen in groups that used “ceramic primers”.
2. When the porcelain priming agent was used with any of the composite resins, the shear bond strength was equal to or better than that stated in the literature as sufficient to sustain normal orthodontic stresses.
3. Damage to the porcelain surface was not observed in any of the groups.

- **“Jia-Kuang Liu, Ching-Hung Chung, Chuan-Yang Chang, and Dar-Bin Shieh” (“AJODO 2005”)<sup>32</sup>** evaluated the difference in shear bond strength between “Clarity”, “Inspire”, and a metal bracket with two different types of composite resins. They also observed the tooth surfaces after brackets were debonded. They concluded that :

1. No statistically significant changes were observed in any of the groups.
2. The majority of the bond failures were seen at the bracket/adhesive interface.

- **Bulent Haydar, Simten Sarikaya, and Zafer C Cehreli (“AO 1999”)<sup>33</sup>** compared the shear bond strength when ceramic and metal brackets were bonded using light-cured compomer, glass ionomer cement, and composite resin. They concluded that :

1. In situations where there are high chances of salivary contamination, “Fuji ortho LC” can be used instead of composite resins with metal brackets. When “ceramic brackets” are used it is best to combine them with “Fuji ortho LC” bonding agent since desirable shear bond strength was observed.
  2. “Compoglass” exhibited lesser than optimal bond strength with metal brackets and higher than the optimal values with “ceramic brackets”.
- **“Mustafa Mehmet Ozarslan, Ozlem Ustun, Ulviye Sebnem Buyukkapan, CaLatay Barutcigil, Nurullah Turker, and Kubilay Barutcigil” (“BioMed Research International 2018”)<sup>3</sup>** assessed the “bond strength of polycrystalline ceramic brackets” to various “CAD/CAM” materials after various surface conditioning methods. They concluded that :
    1. Various surface conditioning methods had a significant impact on “shear bond strength” between “alumina brackets” and “CAD/CAM restorative materials”.
    2. Adequate bond strength was observed in sandblasting and a hydrofluoric acid group.
  - **Anthony D. Viazis, Gerald Cavanaugh, and Richard R. Bevis (“AJODO 1990”)<sup>17</sup>** evaluated the shear bond strength and possible damage to enamel surface after debonding various ceramic and stainless steel brackets initially bonded to extracted premolar teeth. They concluded that :
    1. “Ceramic brackets” with a “silane”-coated base showed more bond strength compared to a mechanically retentive base.
    2. The shear bond strength of “polycrystalline brackets” was more than monocrytalline brackets.
-

3. During debonding, “monocrystalline” brackets were more brittle than “polycrystalline”.

- **S.Kutalmis Buyuk and A.S.Kucukekenci (“AO 2018”)**<sup>14</sup> assessed the “shear bond strength” of “stainless steel brackets” bonded to various “CAD/CAM ceramic materials” using different etchants and primers. They concluded that differences in “CAD/CAM” materials and bonding protocols affect shear bond strength.
- **VK Kalavacharla, NC Lawson, LC Ramp, and JO Burgess (“Operative Dentistry 2015”)**<sup>34</sup> evaluated the impact of “hydrofluoric acid etching” and “silane” application before use of a “universal adhesive” on the “bond strength” between “ceramic material and composite resin”. They concluded that when using the “universal adhesive” in combination with “silane”, it is advantageous to use “5 % HF for 20 seconds” in order to reduce the damage to “ceramic material”. If “silane” application is not done prior to applying an “adhesive”, “9.5% HF for 60 seconds can improve bonding strength”.

## **MATERIALS AND METHODS**

### **SOURCE OF DATA/ LABORATORY DETAILS:**

- The study will be conducted in the “Department of Orthodontics and Dentofacial Orthopaedics, KLE VK institute of Dental Science, KLE Academy of Higher Education and Research, Belagavi”.
- The “shear bond strength” of the brackets will be assessed at “Praj Metallurgy Laboratory, Pune”.

### **SAMPLE SIZE ESTIMATION**

Sample size estimation based on comparison between two means (“Bond strength of ceramic brackets under shear stress: An in vitro report”) from an article by Anthony D. Viazis et al in 1990.

### **FORMULA**

$$n = \frac{2(S^2)}{d^2} [Z_{\alpha/2} + Z_{1-\beta}]^2$$

“ $Z_{1-\beta}$  = Z – value for  $\beta$  level”

“ $Z_{1-\alpha}$  = Z – value for  $\alpha$  level”

S = Combined standard deviation between two groups

d = clinically acceptable error between the two groups

Sample size

Standard deviation in the Ist group  $S1 = 5.077$

Standard deviation in the IInd group  $S2 = 9.897$

Mean difference between Ist and IInd sample =  $9.42=d$

Effect size =  $1.25818084680112$

Alpha Error(%) = 5

Power(%)= 95

sided = 2

**Number needed (n) = 18**

Alpha Error(%)	Power(%)	Sample Size(n)
1	80	16
	90	21

**There are 4 groups. The required sample size per group is 20. Two subgroups come under each group. Since the study has 8 subgroups the sample size per subgroup is 10.**

**“STATISTICAL ANALYSIS”**

The “statistical analysis” was done using “Windows SPSS VERSION 25.0”. The Independent t – test was used to compare between the two study groups. The statistical significance was kept at p – value less than 0.05.

**MATERIALS AND ARMAMENTARIUM**

1. Pre-adjusted edgewise “monocrystalline and polycrystalline brackets”
2. “Hydrofluoric acid (Ultradent porcelain etch 9.6% buffered)”
3. “Transbond XT” primer(3M Unitek)
4. “Transbond XT” adhesive(3M Unitek)

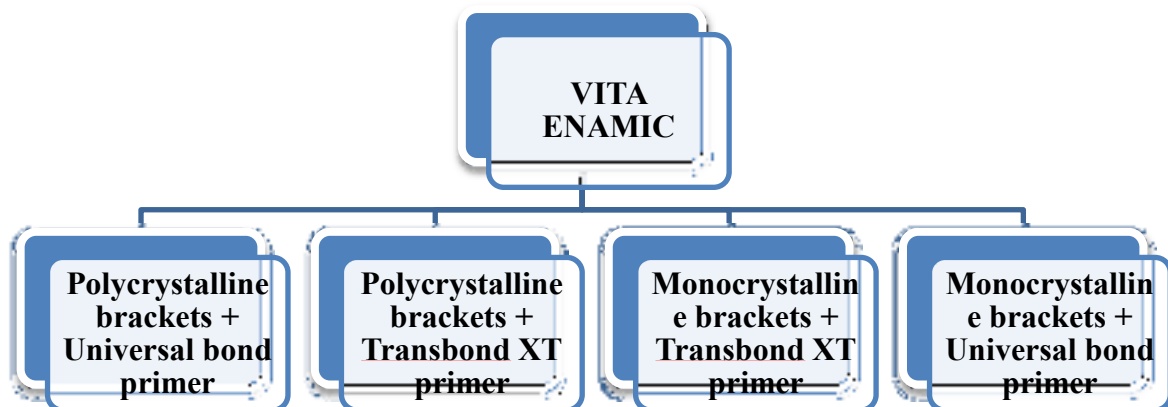
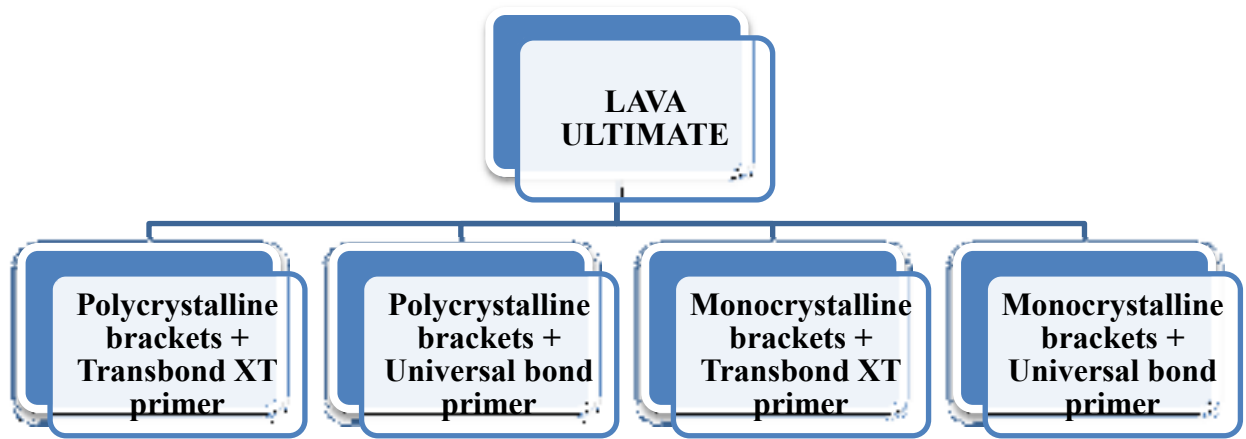
5. Universal bond(3M ESPE)
6. LED curing lamp
7. Bracket tweezer
8. Explorer
9. Universal testing machine
10. Distilled water
11. Stereomicroscope

### **METHODOLOGY**

Monolithic CAD/CAM ceramic blocks of “Lava Ultimate” (“LU”) (n=40) and “hybrid ceramic Vita Enamic” (“VE”)(n=40 ) (5x10x4mm) were made from their corresponding blocks. All samples were then ultrasonically cleaned. The cleaned samples were then embedded in self cure acrylic resin jigs. The polished surface was used for bonding the “ceramic brackets”.

Based on the type of “ceramic brackets” and primer used, forty ceramic samples from each “CAD/CAM group” were categorized into 4 subgroups of ten samples each.

All samples were etched with “HFA (Ultradent Porcelain Etch 9.6 %) for 1 minute, then rinsed with water for 1 minute and air-dried”.



- Polycrystalline + “Transbond XT” group : “Transbond XT adhesive primer (3M Unitek, Monrovia, Calif) was applied to the etched ceramic surface (n=10) according to the manufacturer’s directions, and air-dried for 60 sec. Light cure for 5sec was done using LED device. Light cure bonding resin (Transbond XT, 3M Unitek) was then applied to the base of polycrystalline “ceramic brackets”.
- Polycrystalline + Universal bond group : “Universal single bond (3M ESPE) was applied to the etched ceramic surface (n=10) according to the manufacturer’s directions, and air-dried for 60 sec. Light cure for 5sec was done using LED device. Light cure bonding resin (Transbond XT, 3M Unitek) was then applied to the base of polycrystalline “ceramic brackets”.
- Monocrystalline + “Transbond XT group” : “Transbond XT adhesive primer (3M Unitek, Monrovia, Calif) was applied to the etched ceramic surface (n=10) according to the manufacturer’s directions, and air-dried for 60 sec. Light cure for 5sec was done using LED device. Light cure bonding resin (Transbond XT, 3M Unitek) was then applied to the base of monocrystalline “ceramic brackets”.
- Monocrystalline + Universal bond group : “Universal single bond (3M ESPE) was applied to the etched ceramic surface (n=10) according to the manufacturer’s directions, and air-dried for 60 sec. Light cure for 5sec was done using LED device. Light cure bonding resin (Transbond XT, 3M Unitek) was then applied to the base of monocrystalline “ceramic brackets”.

“The “ceramic brackets” were then placed on the ceramic surface of CAD/CAM materials and a standardized stable pressure was applied to the top surface of the bracket using a bracket tweezer. Excess material was removed using an explorer. For consistency, all the brackets were bonded to the samples by the same clinician (A.K.K).

The light-cured adhesive paste was photopolymerized for a total of 20 seconds from two directions (10 sec each for mesial and distal aspects of bracket) using an LED device (Valo, standard mode, 1000 mW/cm<sup>2</sup> ; Ultradent)".

"Bonded specimens were then stored in deionised water at 37 degree Celsius for 24 hours and then subjected to thermal cycling in deionised water at 5±2 to 55± 2 degree Celsius for 30 cycles with a dwell time of 5 seconds".

### **I. ASSESSMENT AND COMPARISON OF SHEAR BOND STRENGTH**

A knife edge-shaped instrument was placed at the ceramic – resin interface, to test the SBS. "A universal testing machine with cross head speed: 1.0mm/minute was used to measure bond strength. The value of the maximum load required to debond the bracket was recorded in Newtons and converted to Megapascals (1 MPa = 1N/mm<sup>2</sup>). The values were compared with each other".

### **II. ASSESSMENT AND COMPARISON OF ADHESIVE REMNANTS**

After debonding, all teeth were analyzed using light stereomicroscope at x10 magnification to determine the failure interface. Any adhesive left on the surface of teeth after debonding was evaluated using "Modified Adhesive Remnant Index". The criteria were as follows :

"5 = no adhesive paste remained on the ceramic surface".

"4 = less than 10% of adhesive paste remained".

"3 = more than 10%; however, less than 90% of the adhesive paste remained".

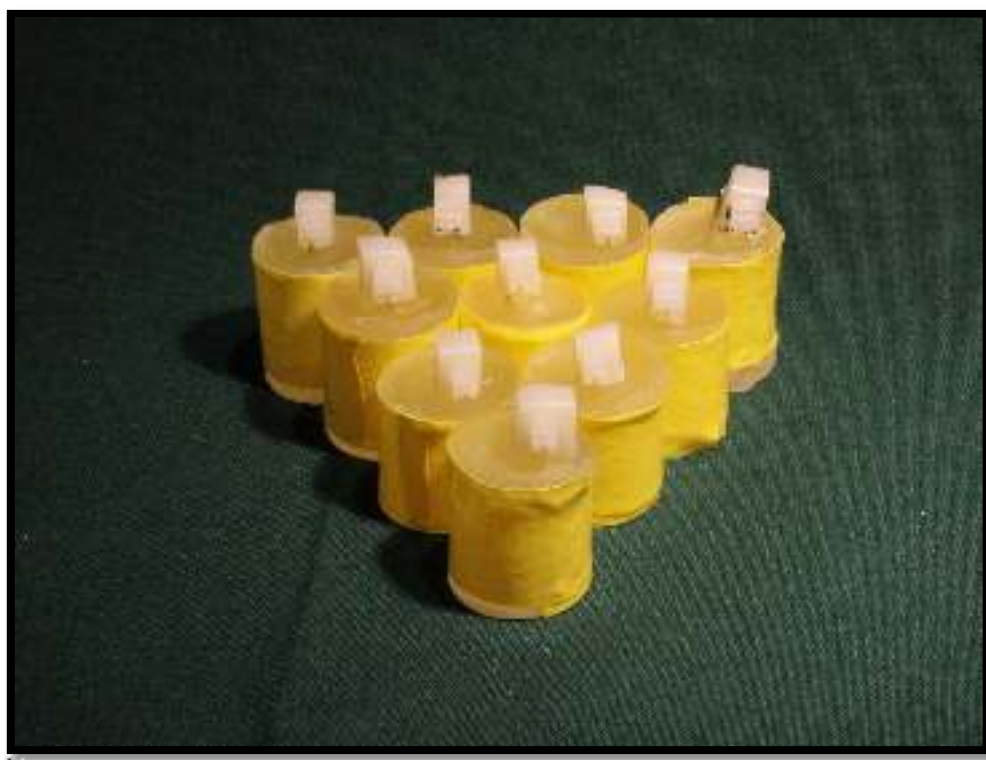
"2 = more than 90% remained".

"1 = all the adhesive paste, with an impression of the bracket base, remained".

**FIGURE 1: Polycrystalline Transbond LU BLACK**



**FIGURE 2: Polycrystalline Universal LU YELLOW**



**FIGURE 3: Monocrystalline Transbond LU GREEN Shiny**



**FIGURE 4: Monocrystalline Universal LU PINK**



**FIGURE 5: Polycrystalline Transbond VE GREY**



**FIGURE 6: Polycrystalline Universal VE GREEN Dark**



**FIGURE 7: Monocrystalline Transbond VE ORANGE**



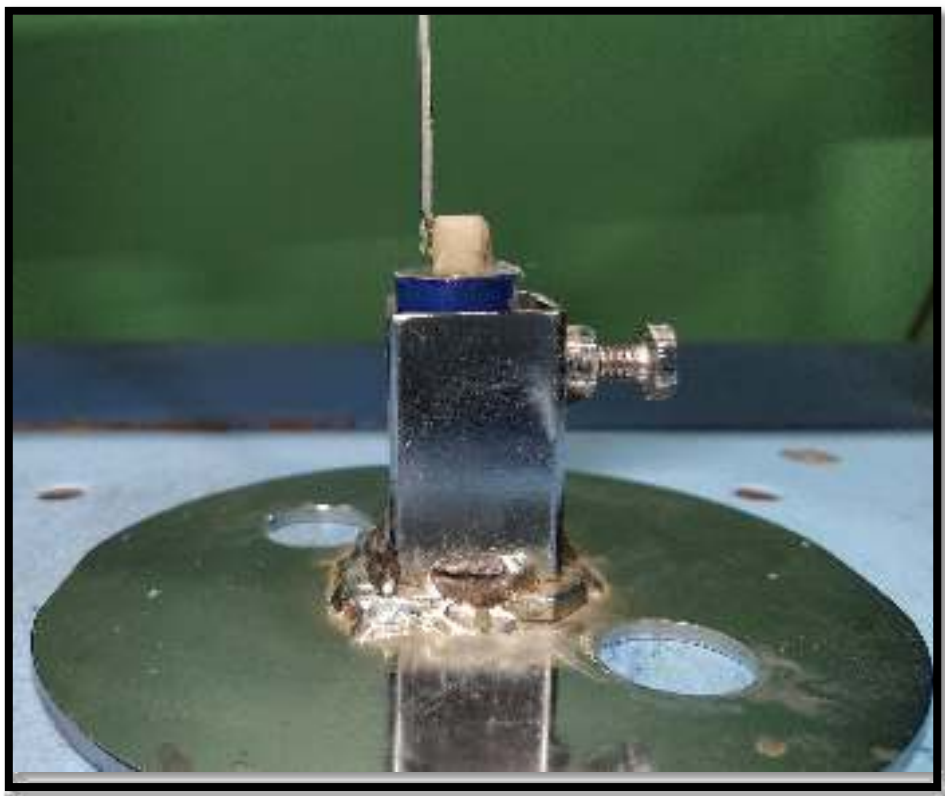
**FIGURE 8: Monocrystalline Universal VE BLUE**



**FIGURE 9: Universal Testing Machine**



**FIGURE 10 : Sample subjected to load for measuring the shear bond strength**



## **RESULTS**

The SBS of “polycrystalline” bracket bonded on “LU” material using “Transbond XT” bonding agent was  $16.37 \pm 2.43$  MPa. Whereas the SBS, when it was bonded using universal bonding agent was  $15.84 \pm 4.22$  MPa.

The SBS of “monocrystalline” bracket bonded on “LU” material using “Transbond XT” bonding agent was  $12.530 \pm 3.30$  MPa. Whereas the SBS, when it was bonded using universal bonding agent was  $14.30 \pm 2.76$  MPa.

The SBS of “polycrystalline” bracket bonded on “VE” material using “Transbond XT” bonding agent was  $17.98 \pm 5.61$  MPa. Whereas the SBS, when it was bonded using universal bonding agent was  $16.911 \pm 6.88$  MPa.

The SBS of “monocrystalline” bracket bonded on “VE” material using “Transbond XT” bonding agent was  $7.92 \pm 1.89$  MPa. Whereas the SBS, when it was bonded using universal bonding agent was  $13.090 \pm 1.89$  MPa.

The SBS of “polycrystalline” bracket bonded on either “LU” or “VE” was more for “Transbond XT” group compared to universal group (statistically insignificant). Whereas, when the “monocrystalline” brackets were bonded on either “LU” or “VE”, the SBS was more for universal group compared to Transbond group.

A “statistically significant difference” in the SBS was noted between universal and “Transbond XT” group when “monocrystalline” brackets were bonded on “VE”. ( $p < 0.05$ ) (Table 1).

When “polycrystalline” and “monocrystalline” brackets were bonded on either “LU” or “VE” using “Transbond XT” or universal bonding agent, “polycrystalline” brackets showed more bond strength compared to “monocrystalline” brackets. A “statistically

significant difference” in the “SBS” was found between “polycrystalline” and “monocrystalline” brackets when they were bonded on either “LU” or “VE” using “Transbond XT” bonding agent. ( $p < 0.05$ ) (Table 2)

When “polycrystalline” brackets were bonded using either Transbond or universal bonding agent on “LU” and “VE” “CAD-CAM” material, “VE” showed more SBS compared to “LU” group. When “monocrystalline” brackets were bonded using either “Transbond XT” or universal bonding agent bonding agent on “LU” and “VE” “CAD-CAM” material, “LU” showed more SBS compared to “VE” group.

A “statistically significant difference” in the SBS was found between “LU” and “VE” “CAD-CAM” material when “monocrystalline” brackets were bonded on them using “Transbond XT” bonding agent (Table 3) ( $P < 0.05$ ).

When comparing the ARI scores between the 8 groups the disparity was statistically significant (Table 4) ( $P < 0.05$ ).

Table 1: Comparison of shear bond strength between the Transbond XT and universal bonding agents

Bonding groups		Number	Mean	Std. Deviation	Mean Difference	t	p- value
Polycrystalline LU	Transbond	10	16.3740	2.43756	.53000	.344	.735
	Universal	10	15.8440	4.22470			
Monocrystalline LU	Transbond	10	12.5340	3.30718	-1.77400	-1.302	.209
	Universal	10	14.3080	2.76020			
Polycrystalline VE	Transbond	10	17.9890	5.61266	1.07800	.384	.706
	Universal	10	16.9110	6.88178			
Monocrystalline VE	Transbond	10	7.9250	1.89389	-5.17100	-4.455	<b>.000*</b>
	Universal	10	13.0960	3.14388			

Table 2: Comparison of shear bond strength between the polycrystalline and monocrystalline brackets

Brackets groups		Number	Mean	Std. Deviation	Mean Difference	t	p- value
Transbond LU	Polycrystalline	10	16.3740	2.43756	3.84000	2.956	<b>.008*</b>
	Monocrystalline	10	12.5340	3.30718			
Universal LU	Polycrystalline	10	15.8440	4.22470	1.53600	.963	.349
	Monocrystalline	10	14.3080	2.76020			
Transbond VE	Polycrystalline	10	17.9890	5.61266	10.06400	5.373	<b>.000*</b>
	Monocrystalline	10	7.9250	1.89389			
Universal VE	Polycrystalline	10	16.9110	6.88178	3.81500	1.595	.128
	Monocrystalline	10	13.0960	3.14388			

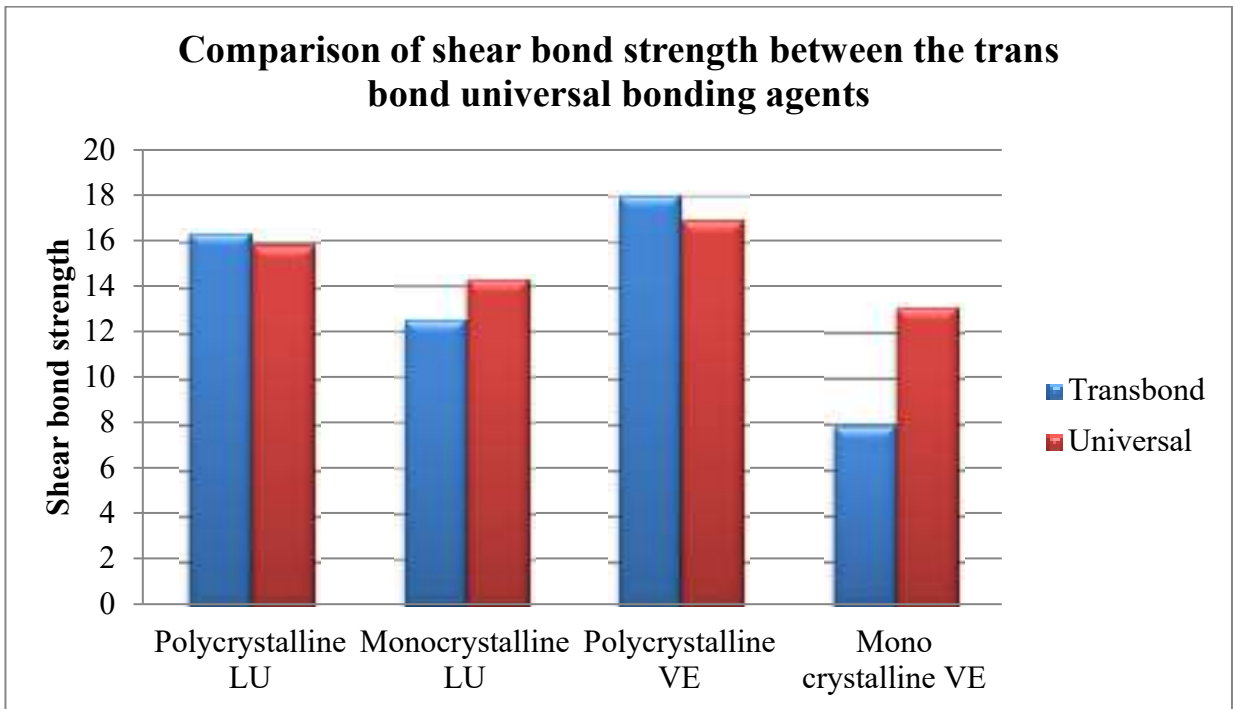
Table 3: Comparison of shear bond strength between the LU and VE CAD-CAM materials

	CAD-CAM groups	Number	Mean	Std. Deviation	Mean Difference	t	p- value
Polycrystalline Transbond	LU	10	16.3740	2.43756	-1.61500	-.835	.415
	VE	10	17.9890	5.61266			
Polycrystalline Universal	LU	10	15.8440	4.22470	-1.06700	-.418	.681
	VE	10	16.9110	6.88178			
Monocrystalline Transbond	LU	10	12.5340	3.30718	4.60900	3.824	<b>.001*</b>
	VE	10	7.9250	1.89389			
Monocrystalline Universal	LU	10	14.3080	2.76020	1.21200	.916	.372
	VE	10	13.0960	3.14388			

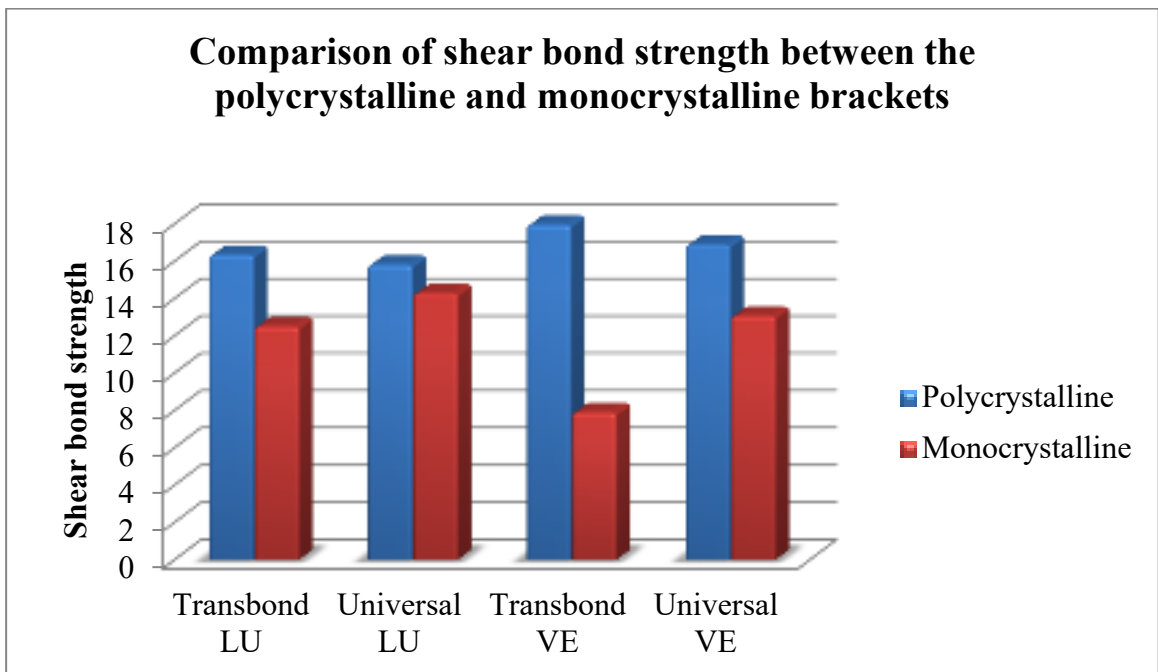
**Table 4: Distribution of Adhesive Remnant Index (ARI) Scores Among the Groups**

GROUPS	ARI SCORE					
		1	2	3	4	5
POLYCRYSTALLINE UNIVERSAL	LU (N=10)	2	1	4	3	-
	VE (N=10)	3	1	-	6	-
POLYCRYSTALLINE TRANSBOND XT	LU (N=10)	-	2	-	6	2
	VE (N=10)	4	1	1	4	-
MONOCRYSTALLINE UNIVERSAL	LU (N=10)	6	2	-	2	-
	VE (N=10)	6	3	1	-	-
MONOCRYSTALLINE TRANSBOND XT	LU (N=10)	2	5	-	2	1
	VE (N=10)	6	3	-	1	-

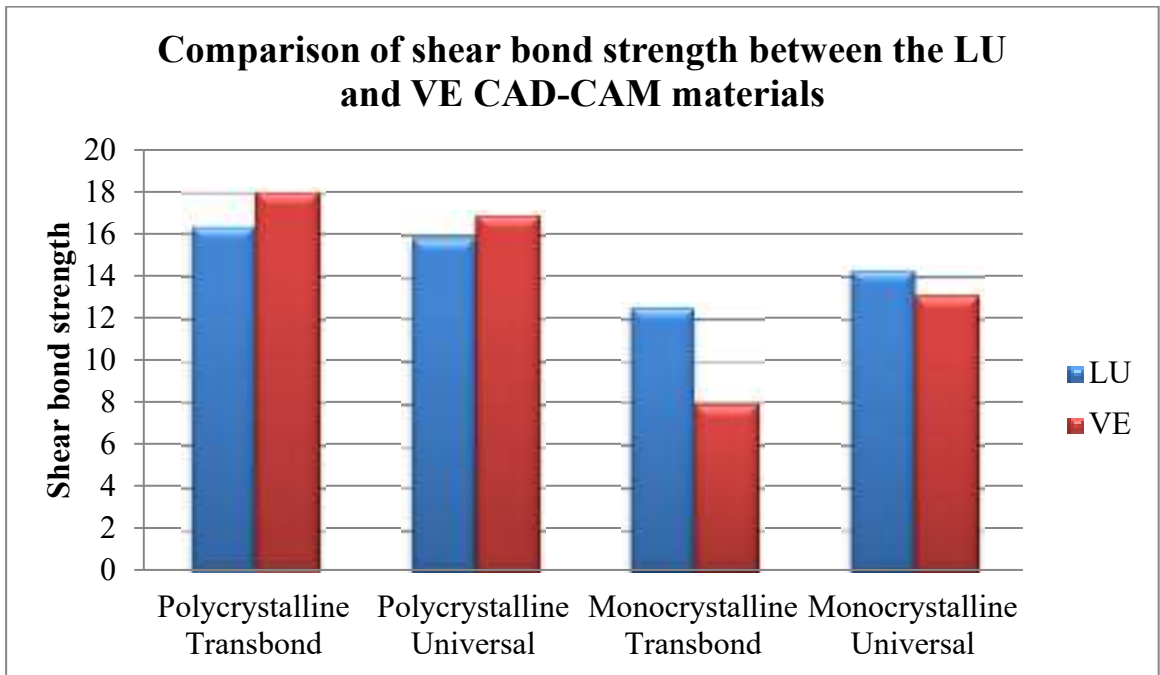
Graph 1



Graph 2



Graph 3



## **DISCUSSION**

“Ceramic brackets were first used in orthodontics in the 1980s to meet the aesthetic requirements of patients”. Better aesthetics, biocompatibility, tolerance to chemical and temperature changes, and superior shear bond strength are all advantages of these brackets over stainless steel brackets.<sup>35</sup>

Metal brackets can be deformed without fracturing, especially in the presence of impurities and at sharp intersections, despite being less aesthetically pleasing than “ceramic brackets”. When compared to “ceramic brackets”, they do not fracture under force and are relatively inexpensive. Metal brackets cause minimal enamel damage during debonding because of their low bond strength.<sup>27</sup>

“Ceramic brackets” bond to the enamel by both mechanical and chemical bonds. “Silane” coupling agent helps in salinization of the bracket which helps in forming the chemical bond and improves the shear bond strength. The stress of debonding can also be moved from the bracket–adhesive contact to the adhesive–enamel interface as a result of a large increase in bond strength, which is more likely to harm the enamel surface during the debonding procedure.<sup>27</sup>

Ceramic bracket base designs can be broadly classified into three groups:

- “Mechanically retentive bases”
- “Silane-treated chemically retentive bases”
- Combination of both

When comparing “mechanically retentive ceramic bracket” to a “silane” treated chemically retentive ceramic bracket in terms of “bond strength” to enamel many investigations have demonstrated that the latter has higher bond strength. But

enamel fractures were more common because the “bond strength” is almost similar to the strength of “enamel”. As a result, mechanically retentive ceramic bracket bases are preferred over chemically retentive ceramic bracket bases.<sup>35</sup>

Many companies offer a variety of base designs, including mechanical ball, dovetail, micro-crystalline, mechanical, dimpled, polymeric bases, and buttons for mechanical retention. Yonus<sup>35</sup> et al in their study assessed the “bond strength” of “ceramic brackets” with different “base designs” and they concluded that “ceramic brackets” with “mechanical base design” had the lowest “shear bond strength” while the bracket system with “microcrystalline base” displayed the highest “shear bond strength”. In our study, both “monocrystalline” and “polycrystalline” brackets have mesh bases.

In adult patients, ceramic restorations are now commonly utilized to restore damaged or missing teeth. Because of the rising demand for “orthodontic treatment” among older patients, the challenge of bonding “brackets” to “porcelain” has arisen.<sup>21</sup>

Although “ceramic and other aesthetic restorations” are commonly used in “prosthetic dentistry” due to benefits such as aesthetic appearance, biocompatibility, and abrasion resistance, bonding brackets to them can be difficult. New forms of “CAD/CAM” ceramics for dental applications have recently been created. The chemical and physical qualities of ceramic material, as well as the type of population, cause differences.<sup>14</sup> “Resin nano-ceramic LU and hybrid ceramic VE” were used in our research.

In numerous investigations bonding “brackets” to “ceramic restorations” have resulted in insufficient “shear bond strength”. This is owing to the fact that ceramic

material is inert. Many procedures are used to improve the bonding strength of orthodontic brackets on the ceramic surface.<sup>14</sup>

Since traditional bonding does not ensure enough adhesion to “porcelain” to endure “orthodontic stresses”, several ways to change the surface properties of “porcelain” to achieve sufficient “bond strength” have been considered.

The techniques proposed can be divided into 3 groups:

- “Chemical”
- “Mechanical”
- “Combination of both”

Sandblasting or coarse diamond stones have been used to mechanically change porcelain surfaces to boost bond strength (“Gillis and Redlich, 1998”). Even though it has been demonstrated that “roughening ceramic surfaces” improves “bond strength”, it simultaneously increases the risk of porcelain cracks associated with debonding.<sup>21</sup>

A systematic review by Bach et al, showed that the highest “bond strength” was for “Empress 2 deglazed surface” with “silane” application, followed by “Finesse glazed surface with the silane application”.<sup>29</sup>

In our research, new generation polymer-based “CAD/CAM” material with glazed surface was used, the reason being that deglazed surfaces have more chance of crack propagation and initiation.

Acids like “HFA” gel, “acidulated phosphate fluoride”, “phosphoric acid”, and “silane” compounds can be used for chemical alteration of the porcelain surface.<sup>24</sup>

9.6% “HFA” gel is the most frequently used ceramic acid etchant. Bach et al in their systematic review, found that “etching for 1min using 9.6 % “HFA” then rinsing for 30 seconds followed by air-drying is a good method to chemically alter porcelain”. According to them, “HFA” etching followed by a “silane” coating is considered the best protocol for bonding brackets to ceramic surfaces.<sup>29</sup>

In our study, the samples were treated with “HFA (Ultra dent Porcelain Etch 9.6%) for 1 minute, then rinsed for 1 minute and air-dried without application of “silane particles”, because application of “silane” particles will increase bond strength above the maximum limit, potentially causing porcelain fracture during debonding.

Even though using “9.6 % HF” acid improved bond strength, Goksu et al found that the difference between groups “etched” with “5% and 9.6% HF acid” was not statistically significant in their investigation. As a result, “5% HFA” may be recommended for intraoral treatments to avoid “tissue irritation” while maintaining bond strength.<sup>36</sup>

According to a previous study done by Mustafa et al sandblasting using 50 $\mu$ m Al<sub>2</sub>O<sub>3</sub> and “HF acid” application on “CAD/CAM” materials prior to bonding “ceramic brackets” resulted in inadequate bond strength.<sup>3</sup>

“According to Reynolds, the ideal bond strength between an orthodontic bracket and porcelain should be 6–8 MPa”. In the current study, all the groups had higher “SBS” than the optimal range, except one group (“monocrystalline” bracket bonded to VE using “Transbond XT”) which was within the normal range.<sup>10</sup>

“Thurmond et al discovered that bond strength greater than 13MPa between ceramic and adhesive bonding can produce porcelain fracture”.<sup>12</sup>

A previous study done by Benjakul et al assessed if various base designs in “ceramic brackets” affected shear bond strength when bonding to ceramic surfaces. The study revealed that all the groups showed shear bond strength greater than 15MPa and “stereoscopic examination” showed that no damage to the “ceramic surfaces” was observed in any group.<sup>30</sup>

Yadav et al, assessed if the “shear bond strength” of “composite resin” was influenced by various “ceramic surface” treatments. Some groups in the study had shear bond strength exceeding 13MPa. Adhesive failures between ceramic and composite resin were seen in all the groups except one. In HF/“silane” group (20.8 MPa) a cohesive failure in the ceramic was observed.<sup>4</sup>

In the current study, the “shear bond strength” between “ceramic brackets” and “CAD/CAM material” ranged from 7.9250 to 17.98 “MPa”. The “bond strength” values determined in all groups were more than the maximum limit value (13MPa) except when “monocrystalline” brackets were bonded to VE (7.9250 MPa) and Lava ultimate (12.534MPa) using “Transbond” bonding agent and “monocrystalline” brackets bonded to VE using universal bonding agent (13.0960). Stereoscopic examination revealed no damage to “CAD/CAM” material. Table no 4– shows the ARI score of all the groups in the study.

The possibility of ceramic damage in clinical practice when “debonding” the “brackets” was reported to be very less or non-existent. This discrepancy could be due to the fact that clinically “appropriate and safe debonding techniques” with suitable “debonding forces” differ from laboratory “shear testing forces”. Porcelain fractures, on the other hand, cannot be ruled out. As a result, it's impossible to say whether the

silica coating approach will increase the danger of ceramic degradation in clinical settings.<sup>4</sup>

Hellak et al, evaluated the “shear bond strength” of two “self-etching no-mix adhesives” (“iBond and Scotchbond”) and “Transbond XT” and found that Scotchbond universal provides the best bonding on all other types of surface (metal, composite, and porcelain), with no need for additional primers. In the present study, there was no significant difference between “Transbond XT” and Universal bonding agent in all groups except when “monocrystalline” brackets were bonded to VE which showed that universal bonding agent was better. This might be due to the fact that etching was done using HF acid prior to the application of the bonding agent.<sup>6</sup>

Chaconas<sup>37</sup> et al and Gautam<sup>16</sup> et al compared the shear bond strength of “monocrystalline” and “polycrystalline” brackets when bonded to ceramic surfaces; they found that “polycrystalline” brackets have higher shear bond strength than “monocrystalline” brackets, which is similar to the finding in our study in which “polycrystalline” brackets showed the higher shear bond strength when bonded to “CAD/CAM” material.

In this study, “CAD/CAM” ceramic materials “VE and LU” were compared. Various “SBSs” were obtained in these “ceramic groups” wherein different “ceramic brackets” and “bonding agents” were used. This disparity could be because of variation in the process of “ceramic restoration” and variation in their “chemical and physical properties”.

## **CONCLUSION**

Based on the recorded data and findings with the statistical analysis, the following “conclusions” can be made:

1. The type of “ceramic brackets” and “CAD/CAM” material had an impact on shear bond strength.
2. “Polycrystalline” brackets had higher bond strength than “monocrystalline” brackets.
3. The type of bonding agent used did not have a significant impact on shear bond strength.
4. All the groups have shown shear bond strength exceeding the recommended range, so additional use of “silane” coupling agent is not required as it may degrade and damage “CAD/CAM” surfaces during debonding procedure.

## **SUMMARY**

Adult patients seeking orthodontic treatment has increased significantly in the last decade. In spite of the emergence of Invisalign, a large group of adult patients still favor “ceramic brackets” as choice for esthetic orthodontic treatment. With the increase in age, patients may require certain crowns and dental restorations in addition to orthodontic therapy. With the emergence of “CAD/CAM” in dentistry, single tooth crown restorations may now be made both chairside and in the lab.

So, it has become very important for orthodontist to find a proper bonding protocol which gives optimal bond strength to bond “metal and ceramic brackets” to the newer “CAD/CAM materials”.

In the current study we have evaluated the SBS of “monocrystalline” and “polycrystalline” “ceramic brackets” on LU and VE “CAD/CAM” blocks using “Transbond XT” and Universal single bond bonding agents.

Based on the type of “ceramic brackets” and primer used, forty ceramic samples from each “CAD/CAM group” were categorized into 4 subgroups of 10 samples each. SBS were tested using Universal testing machine followed by assessment of Adhesive Remnant Index using Stereomicroscope based on Olsen and Bishara scores.

The result showed that the type of “ceramic brackets” and “CAD/CAM material” had an impact on “shear bond strength”. The type of bonding agent did not have a big impact on “SBS”. Clinically acceptable “bond strength” values were seen in all the groups.

**BIBLIOGRAPHY**

1. Schabel BJ, Franchi L, Baccetti T, McNamara Jr JA. Subjective vs objective evaluations of smile esthetics. *American journal of orthodontics and dentofacial orthopedics*. 2009 Apr 1;135(4):S72-9.
2. McNamara L, McNamara Jr JA, Ackerman MB, Baccetti T. Hard-and soft-tissue contributions to the esthetics of the posed smile in growing patients seeking orthodontic treatment. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2008 Apr 1;133(4):491-9.
3. Özarslan MM, Üstün Ö, Buyukkaplan US, Barutcigil Ç, Türker N, Barutcigil K. Assessment the bond strength of ceramic brackets to CAD/CAM nanoceramic composite and interpenetrating network composite after different surface treatments. *BioMed research international*. 2018 May 30;2018.
4. Yadav S, Upadhyay M, Borges GA, Roberts WE. Influence of ceramic (feldspathic) surface treatments on the micro-shear bond strength of composite resin. *The Angle Orthodontist*. 2010 Jul;80(4):765-70.
5. Bühner Samra AP, Morais E, Mazur RF, Vieira SR, Nunes Rached R. CAD/CAM in dentistry-a critical review. *Revista Odonto Ciencia*. 2016 Jul 1;31(3).
6. Hellak A, Ebeling J, Schauseil M, Stein S, Roggendorf M, Korbmacher-Steiner H. Shear bond strength of three orthodontic bonding systems on enamel and restorative materials. *BioMed research international*. 2016 Sep 21;2016.
7. Saraç YŞ, Külünk T, Elekdağ-Türk S, Saraç D, Türk T. Effects of surface-conditioning methods on shear bond strength of brackets bonded to different all-ceramic materials. *The European Journal of Orthodontics*. 2011 Dec 1;33(6):667-72.


8. Zhang ZC, Qian YF, Yang YM, Feng QP, Shen G. Bond strength of metal brackets bonded to a silica-based ceramic with light-cured adhesive. *Journal of Orofacial Orthopedics/Fortschritte der Kieferorthopädie*. 2016 Sep;77(5):366-72.
9. Guarita MK, Moresca AH, Losso EM, Moro A, Moresca RC, Correr GM. Effect of different surface treatments for ceramic bracket base on bond strength of rebonded brackets. *Brazilian dental journal*. 2015 Jan;26:61-5.
10. Reynolds IR. A review of direct orthodontic bonding. *British journal of orthodontics*. 1975 Jul 1;2(3):171-8.
11. Lee-Knight CT, Wylie SG, Major PW, Glover KE, Grace M. Mechanical and electrothermal debonding: effect on ceramic veneers and dental pulp. *American journal of orthodontics and dentofacial orthopedics*. 1997 Sep 1;112(3):263-70.
12. Thurmond JW, Barkmeier WW, Wilwerding TM. Effect of porcelain surface treatments on bond strengths of composite resin bonded to porcelain. *The Journal of prosthetic dentistry*. 1994 Oct 1;72(4):355-9.
13. Saraç YŞ, Külünk T, Elekdağ-Türk S, Saraç D, Türk T. Effects of surface-conditioning methods on shear bond strength of brackets bonded to different all-ceramic materials. *The European Journal of Orthodontics*. 2011 Dec 1;33(6):667-72.
14. Buyuk SK, Kucukekenci AS. Effects of different etching methods and bonding procedures on shear bond strength of orthodontic metal brackets applied to different CAD/CAM ceramic materials. *The Angle Orthodontist*. 2018 Mar;88(2):221-6.

15. Hosseini MH, Sobouti F, Etemadi A, Chiniforush N. Shear bond strength of metal brackets to feldspathic porcelain treated by Nd: YAG laser and hydrofluoric acid. *Lasers in medical science*. 2015 Feb;30(2):837-41.
16. Gautam P, Valiathan A. Ceramic brackets: in search of an ideal!. *Trends in Biomaterials and Artificial Organs*. 2007 Jan 1;20(2):117-22.
17. Viazis AD, Cavanaugh G, Bevis RR. Bond strength of ceramic brackets under shear stress: an in vitro report. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1990 Sep 1;98(3):214-21.
18. Schmage P, Nergiz I, Herrmann W, Özcan M. Influence of various surface-conditioning methods on the bond strength of metal brackets to ceramic surfaces. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2003 May 1;123(5):540-6.
19. Eliades T, Viazis AD, Eliades G. Bonding of ceramic brackets to enamel: morphologic and structural considerations. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1991 Apr 1;99(4):369-75.
20. Cacciafesta V, Jost-Brinkmann PG, Süßenberger U, Miethke RR. Effects of saliva and water contamination on the enamel shear bond strength of a light-cured glass ionomer cement. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1998 Apr 1;113(4):402-7.
21. Abu Alhaija ES, Al-Wahadni AM. Shear bond strength of orthodontic brackets bonded to different ceramic surfaces. *The European Journal of Orthodontics*. 2007 Aug 1;29(4):386-9.
22. Eslamian L, Borzabadi-Farahani A, Mousavi N, Ghasemi A. A comparative study of shear bond strength between metal and ceramic brackets and artificially aged

- composite restorations using different surface treatments. *The European Journal of Orthodontics*. 2012 Oct 1;34(5):610-7.
23. Elekdag-Turk S, Sarac YS, Turk T, Sarac D. The effect of a light-emitting diode on shear bond strength of ceramic brackets bonded to feldspathic porcelain with different curing times. *The European Journal of Orthodontics*. 2007 Jun 1;29(3):299-303.
24. Olsen ME, Bishara SE, Boyer DB, Jakobsen JR. Effect of varying etching times on the bond strength of ceramic brackets. *American journal of orthodontics and dentofacial orthopedics*. 1996 Apr 1;109(4):403-9.
25. Atsü SS, Gelgör İE, Sahin V. Effects of silica coating and silane surface conditioning on the bond strength of metal and ceramic brackets to enamel. *The Angle Orthodontist*. 2006 Sep;76(5):857-62.
26. Abu Alhajja ES, Abu AlReesh IA, AlWahadni AM. Factors affecting the shear bond strength of metal and ceramic brackets bonded to different ceramic surfaces. *The European Journal of Orthodontics*. 2010 Jun 1;32(3):274-80.
27. Reddy YG, Sharma R, Singh A, Agrawal V, Agrawal V, Chaturvedi S. The shear bond strengths of metal and ceramic brackets: An in-vitro comparative study. *Journal of clinical and diagnostic research: JCDR*. 2013 Jul;7(7):1495.
28. Mirzakouchaki B, Kimyai S, Hydari M, ShahrbaF S, Mirzakouchaki-Boroujeni P. Effect of self-etching primer/adhesive and conventional bonding on the shear bond strength in metallic and ceramic brackets. *Medicina oral, patologia oral y cirugia bucal*. 2012 Jan;17(1):e164.
29. Grewal Bach GK, Torrealba Y, Lagravère MO. Orthodontic bonding to porcelain: a systematic review. *The Angle Orthodontist*. 2014 May;84(3):555-60.

30. Samruajbenjakul B, Kukiattrakoon B. Shear bond strength of ceramic brackets with different base designs to feldspathic porcelains. *The Angle Orthodontist*. 2009 May;79(3):571-6.
31. Whitlock III BO, Eick JD, Ackerman Jr RJ, Glaros AG, Chappell RP. Shear strength of ceramic brackets bonded to porcelain. *American Journal of Orthodontics and Dentofacial Orthopedics*. 1994 Oct 1;106(4):358-64.
32. Liu JK, Chung CH, Chang CY, Shieh DB. Bond strength and debonding characteristics of a new ceramic bracket. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2005 Dec 1;128(6):761-5.
33. Haydar B, Sartkaya S, Çehreli ZC. Comparison of shear bond strength of three bonding agents with metal and ceramic brackets. *The Angle Orthodontist*. 1999 Oct;69(5):457-62.
34. Kalavacharla VK, Lawson NC, Ramp LC, Burgess JO. Influence of etching protocol and silane treatment with a universal adhesive on lithium disilicate bond strength. *Operative Dentistry*. 2015;40(4):372-8.
35. Ansari MY, Agarwal DK, Gupta A, Bhattacharya P, Ansar J, Bhandari R. Shear bond strength of ceramic brackets with different base designs: Comparative in-vitro study. *Journal of clinical and diagnostic research: JCDR*. 2016 Nov;10(11):ZC64.
36. . Trakyalı G, Malkondu Ö, Kazazoğlu E, Arun T. Effects of different silanes and acid concentrations on bond strength of brackets to porcelain surfaces. *The European Journal of Orthodontics*. 2009 Aug 1;31(4):402-6.
37. Chaconas SJ, Caputo AA, Niu GS. Bond strength of ceramic brackets with various bonding systems. *The Angle Orthodontist*. 1991 Mar;61(1):35-42.

ANNEXURES –I - ETHICAL APPROVAL CERTIFICATE

 **Research and Ethics Committee**  
**KLE V K INSTITUTE OF DENTAL SCIENCES**  
**KLE University**  
Accredited 'A' Grade by NAAC Placed in Category 'A' by MHRD (GoI)  
Nehru Nagar, Belagavi - 590 010, Karnataka State  
☎: 0831-2470362 Web: <http://www.kledental-bgm.edu.in>  
FAX: 0831-2470640 E-mail: [principal@kledental-bgm.edu.in](mailto:principal@kledental-bgm.edu.in)

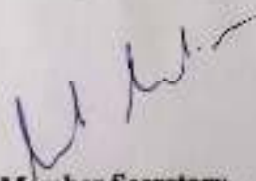
SI. No. : 1315

**CERTIFICATE**

*This is to Certify that the synopsis titled*

COMPARATIVE EVALUATION OF SHEAR BOND STRENGTH OF  
MONOCRYSTALLINE & POLYCRYSTALLINE CERAMIC BRACKETS  
USING TWO DIFFERENT BONDING SYSTEMS ON Submitted by  
TWO DIFFERENT CAD/CAM MATERIALS - IN VITRO STUDY  
Dr. AKIN K. KORATH P. G. Student /

Staff, Guided by DR. ROHAN YATTARUKI from Department of  
ORTHODONTICS & DENTOFACIAL has been critically evaluated by  
ORTHODONTICS  
committee members and granted ethical clearance to conduct the above  
mentioned study

Date : 

**Member Secretary**  
Research and Ethical Committee  
KLEVK Institute of Dental Sciences  
Belagavi

**Chairman**  
Research and Ethical Committee  
KLEVK Institute of Dental Sciences  
Belagavi

## ANNEXURES –II - MASTER CHART

<b>Group 1: Polycrystalline Transbond LU BLACK</b>					<b>Group 2: Polycrystalline Universal LU YELLOW</b>				
Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)	Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)
1	No Color	No.1	135.10	15.44	1	No Color	No.1	145.30	16.61
2		No.2	145.30	16.61	2		No.2	208.40	23.82
3		No.3	121.55	13.89	3		No.3	179.90	20.56
4		No.4	129.70	14.82	4		No.4	163.90	18.73
5	Yellow	No.1	221.50	18.08	5	Yellow	No.1	135.60	11.07
6		No.2	197.10	16.09	6		No.2	155.20	12.67
7		No.3	187.40	15.30	7		No.3	129.15	10.54
8	Black	No.1	170.20	13.89	8	Black	No.1	170.20	13.89
9		No.2	215.25	17.57	9		No.2	181.70	14.83
10	Blue	No.1	270.10	22.05	10	Blue	No.1	192.60	15.72
<b>Average</b>				<b>16.37</b>	<b>Average</b>				<b>15.84</b>

<b>Group 3 : Monocrystalline Transbond LU GREEN Shiny</b>					<b>Group 4 : Monocrystalline Universal LU PINK</b>				
Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)	Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)
1	Black	No.1	121.50	9.91	1	Black	No.1	181.30	14.80
2		No.2	147.60	12.05	2		No.2	168.50	13.76
3		No.3	161.20	13.16	3		No.3	195.10	15.93
4		No.4	130.40	10.64	4		No.4	160.20	13.08
5		No.5	175.70	14.34	5	Red	No.1	130.30	10.64
6	Red	No.1	239.50	19.55	6	Yellow	No.1	117.90	9.62
7		No.2	178.80	14.60	7	Green	No.1	198.50	18.90
8	Green	No.1	143.15	13.63	8		No.2	155.70	14.83
9	Blue	No.1	86.70	8.26	9	Blue	No.1	178.10	16.96
10	White	No.1	80.50	9.20	10	White	No.1	127.40	14.56
<b>Average</b>				<b>12.53</b>	<b>Average</b>				<b>14.31</b>

<b>Group 5 : Polycrystalline Transbond VE GREY</b>					<b>Group 6 : Polycrystalline Universal VE GREEN Dark</b>				
Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)	Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)
1	No Color	No.1	256.60	29.32	1	No Color	No.1	210.20	24.02
2		No.2	208.50	23.83	2		No.2	189.20	21.62
3		No.3	185.10	21.15	3		No.3	165.80	18.95
4	Black	No.1	196.40	16.04	4		No.4	192.10	21.95
5		No.2	210.20	17.16	5		No.5	221.60	25.32
6		No.3	225.90	18.44	6		No.6	177.70	20.31
7		No.4	216.80	17.70	7	Yellow	No.1	89.80	7.33
8	Yellow	No.1	135.50	11.06	8		No.2	110.45	9.01
9		No.2	152.50	12.45	9		No.3	123.90	10.11
10	Blue	No.1	156.10	12.74	10	Black	No.1	128.50	10.49
<b>Average</b>				<b>17.99</b>	<b>Average</b>				<b>16.91</b>

<b>Group 7 : Monocrystalline Transbond VE ORANGE</b>					<b>Group 8 : Monocrystalline Universal VE BLUE</b>				
Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)	Sr. No.	Sample ID		Maximum Load (N)	Shear Bond Strength (MPa)
1	Black	No.1	120.25	9.82	1	Black	No.1	150.40	12.28
2		No.2	103.60	8.46	2		No.2	173.20	14.14
3		No.3	138.40	11.30	3		No.3	188.70	15.40
4		No.4	100.65	8.22	4		No.4	119.90	9.79
5	Yellow	No.1	54.50	4.45	5		No.5	198.60	16.21
6	Blue	No.1	78.50	7.48	6	Red	No.1	78.10	6.38
7	Green	No.1	67.10	6.39	7	Blue	No.1	126.50	12.05
8	White	No.1	75.10	8.58	8	White	No.1	145.30	16.61
9		No.2	69.90	7.99	9		No.2	117.10	13.38
10		No.3	57.40	6.56	10		No.3	128.80	14.72
<b>Average</b>				<b>7.93</b>	<b>Average</b>				<b>13.10</b>