Evaluation of Clinical Performance of Monolithic Zirconia Single Crowns for Posterior Teeth: An Interventional Study

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Abstract

Background Numerous studies highlight the excellent biological and technical performance of metal-ceramic restorations. However, short comings such as blue-grey gingival discoloration and metal opacity have driven a shift toward all-ceramic restorations. Achieving esthetics while preserving tooth structure remains a clinical challenge, but advances in materials and skilled clinicians have enabled esthetic restorations with high patient satisfaction. Advancements in digital technology have enhanced monolithic zirconia restorations, providing greater precision and strength. However, clinical data on their biological effects and impact on opposing dentition remain limited. **Aim:** This study aims to assess the clinical performance of CAD/CAM-fabricated monolithic zirconia crowns for posterior teeth. **Study setting and design:** An in-vivo prospective study conducted on patients requiring a single monolithic zirconia crown on posterior teeth**. Materials and methods:** Forty-five patients receiving monolithic zirconia crowns on posterior teeth were evaluated at 6, 12, and 18 months. Crown quality was assessed using modified CDA criteria, periodontal health using Gingival Index and probing depth, and antagonist tooth wear through superimposed digital impressions at 18 months. Descriptive statistics and unpaired t-tests ($P < 0.05$) were used for analysis. **Results:** All crowns remained within excellent or acceptable ranges as per Modified CDA Criteria over 18 months. Although healthy gingiva values declined to 71.2% and probing depths over 3 mm increased, the changes lacked statistical significance ($p > 0.05$). The average antagonist tooth wear was 63 ± 3 µm, remaining within clinically acceptable limits. **Conclusion:** Monolithic zirconia crowns showed excellent performance, minimal wear, and durability over 18 months, making them a reliable alternative to metal-ceramic restorations for single posterior teeth.

Keywords: Monolithic Zirconia Crowns, Clinical performance, Complications, Enamel wear, Antagonist teeth

Introduction

The high mechanical strength offered by metal-ceramic restorations has made it an excellent treatment option for more than 50 years.[1] Numerous systematic reviews have studied metal ceramic crowns concluding their excellent performance, from both biologic and technical aspects.[2] However, the black blue grey discoloration at the gingival margins[3] and opacity of the metal maybe revealed over time, thereby affecting patient esthetics. With the rapid rise in esthetic demands of the patients, the popularity of all ceramic crowns increased as they closely resemble the appearance of natural dentition.[4]

The integration of digital technology in dental practise has made highly precise restorations a possibility using materials like Lithium Disilicate and Zirconia.[5]

Zirconia emerged in 1990 as an alternative option owing to its mechanical properties and the esthetic advantages of all-ceramic crowns.[4]A monolithic zirconia crown restoration is designed and manufactured from one solid block of zirconium oxide ceramic through a CAD/CAM system. Digital technology eliminates the necessity of veneering porcelain.[6] This material promotes minimal tooth preparation in comparison to conventional metal-ceramic crowns.[2] It exhibitsexcellent biocompatibility, reduction in wear of the antagonist teeth, non-occurrence of veneer chipping.[7] It demonstrates easiness to polish,[7] high hardness,[7] high strength,[1] low thermal conductivity,[7] and chemical stability,[7,] shorter laboratory time and fewer clinical sessions in fabrication of prosthesis.[7]

Consideration of the restorative material's wear resistance is essential in the treatment planning process. Tooth wear is a complex, multifactorial phenomenon caused mainly due to the difference in wear properties of restorative material and that of natural teeth. Wear of the opposing teeth results in loss of vertical dimension, thereby affecting the functioning of the orofacial system. Numerous invitro studies have evaluated the wear caused by monolithic zirconia on opposing natural enamel The studies indicated that polished zirconia restorations cause less wear of opposing enamel in comparison with glazed zirconia or feldspathic porcelain restorations. While there are many invitro studies, they allow precise control of environment, thereby showing limited correlation between the invitro observations and clinical performance.[8]

The growing adoption of monolithic full-contour zirconia restorations in dentistry raises several important considerations, including the accuracy of tooth color reproduction, surface characteristics, long-term chemical stability, and wear potential.[9]

Elsayed et al studied the long-term outcome of monolithic zirconia crowns.[2, 10]In vitro studies have concluded the use of monolithic zirconia restorations for individuals with parafunctional habits, unfavorable occlusion, previous fractures and limited restorative space, mainly due to their superior performance and mechanical strength.[7]

Konstantinidis et al evaluated the clinical outcomes of monolithic zirconiaposterior single crowns over a period of 1 year.[5]Bömicke et al studied the short-term survival and success of 90 zirconia crowns over 3 years.[11]

Only a limited number of clinical studies have investigated periodontal health and treatment outcomes of the abutment and opposing teeth following the placement of monolithic zirconia crowns.[6]

There is limited scientificdata regarding the clinical and biological outcomes of monolithic zirconia, necessitating more in vivo studies to verify the benefits offered by the same. The aim of this study is to evaluate the clinical performance of monolithic zirconia crowns fabricated by Computer aided designing/ Computer aided manufacturing on posterior teeth restorations during a 18 month follow up. The null hypothesis is that no differences will be found at baseline and at the follow-up periods among the studied parameters.

Materials and methodology

The study commenced subsequent to obtaining approval from the Institutional Ethics Committee IEC/ PROS23 /178/ V2.The study was conducted in the Department of Prosthodontics and Crown and Bridge (A. J. Institute of Dental Sciences, Mangalore). Fortyfive participants (25 male and 20 female), in need of a posterior monolithic zirconia crown were selected. The sample size was determined using data drawn from previous studies.[2]A written and signed consent was collected from each participant. The age of the subjects ranged from 21 to 58 years.

The patient inclusion criteria were as follows: patients aged ≥ 20 years old and ≤ 60 years old, patients who require a premolar or a molar crown restoration (following endodontic treatment, gross restorations, or cusp fracture), and who need a change in preexisting crowns,patients with minimum prepared tooth height of 3mm, patients with healthy opposing natural teeth, periodontally sound abutment teeth, patients with good oral hygiene, patients with no history of allergy to any medication or material and patients willing to contributeto the study. The patients were excluded based on the following criteria: parafunction such as bruxism, severe systemic disease, temporomandibular joint disorders, active caries and periodontal problems,unacceptable oral hygiene, history of allergy to any medication or material, pregnant women and noncompliant participants.

All participants were scheduled for Oral Prophylaxis prior to the commencement of this study. All clinical interventions were carried out by a single clinician, including preparation of abutment tooth, intraoral scanning, temporization and cementation. Molars and premolars were prepared according to the standard protocol to receive a monolithic zirconia crown.[1]Digital impressions of the reduced tooth surface were made using an intraoral scanner (Prime Scan, Dentsply Sirona, Pfungstadt, Germany). A temporary crown was fabricated using Bis-acrylic temporization material (3M ESPE Protemp 4, 3M Deutschland, Germany) and retained with a temporary luting cement (3M ESPE RelyX™ Temp NE, Conway Avenue, St. Paul, USA).

A single dental technician designed and milled the monolithic zirconia (Cercon ht, Dentsply Sirona, Hanau-Wolfgang, Germany) crowns with a computer-aided design and computer-aided manufacturing (CAD-CAM) unit (Dentsply Sirona, inLab MC X5,

Bensheim, Germany). All crown surfaces were glazed, with the exception of the occlusal surfaces, which were polished using diamond polishing paste (Renfert Polish, Hilzingen, Germany) and silicone polishing wheels.

In instances where chairside occlusal adjustments were necessary, the zirconia restorations were sent back to the dental technician for repolishing prior to placement. The crowns were then cemented using resin cement (3M™ RelyX™ U200 Self-Adhesive Resin Cement, 3M Deutschland, Germany). Oral hygiene instructions were explained to each patient after cementation of the crown. Digital impressions were made of the opposing arches at the time of cementation.

Follow-up evaluation was performed at 6 months, 12 months and 18 months. The survival of the prosthesis was rated using the modified California Dental Association Criteria[12] to evaluate the marginal integrity, color, surface texture and anatomic form. Periodontal parameters were assessed using Gingival index (GI)[4] and Pocket Probing Depth (PPD)[4]. Any specific mechanical or biologic complications were also assessed. The data was collected by two calibrated examiners.

Digital impressions of the opposing teeth were made at the 18 month follow up (Figure 1). The scanned files were then transferred in Standard Tesselation Language (STL) format to the laboratory for superimposition. The scans were then imported into Exocad 3.0 Galway. Using the “mesh alignment” tool the scans were aligned, primarily focusing on non-altered adjacent teeth to maintain accuracy. A Vertical/ Oblique sectioning plane was created to pass through the functional cusp of the opposing tooth in contact with the crown. The linear distance was then measured using the “measure tool” to assess the amount of wear (Figure 2) (Figure 3).

Data analysis was performed using SPSS for Windows [SPSS ver 26.0, Armonk, NY]. Descriptive statistics in the form of frequency distribution and percentage was used to describe the data. A Cochran’s Q test was used to compare the distribution of participants according to gingival health and probing depth. The mean tooth wear values were analyzed between gender and anatomic location using unpaired t-test. Tables and graphs were used to present the results. The level of significance were set at $P < 0.05$.

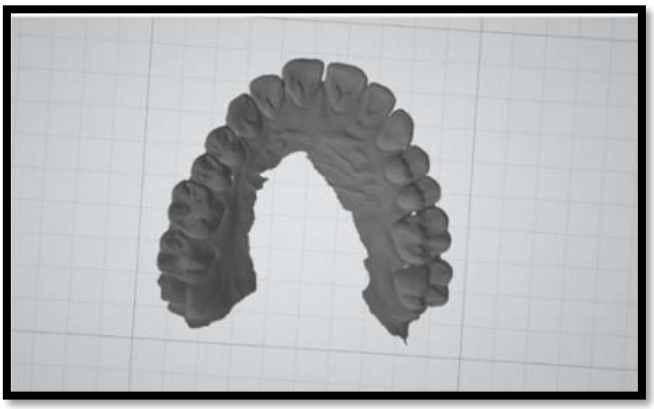


Figure 1 - Digital impression of opposing arch

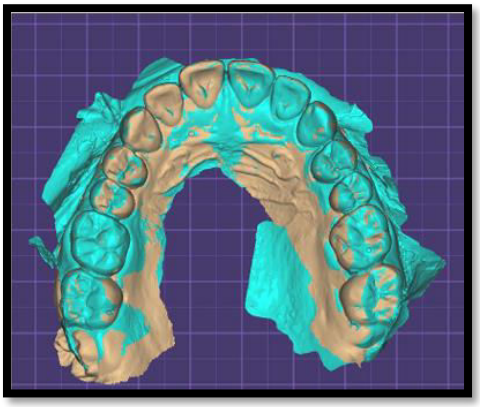


Figure2- Superimposition using Exocad 3.0 Galway

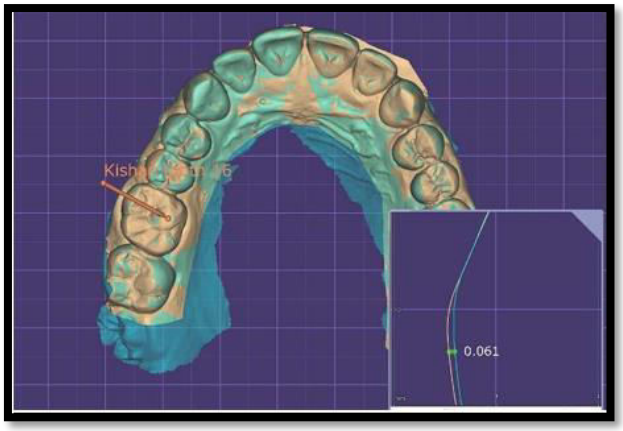


Figure3 – Wear assessment using Exocad 3.0 Galway

Results

The crowns were placed on 18 premolars and 27 molars, 40% of samples were maxillary teeth and 60% were mandibular teeth. No participants were lost to follow up. No biologic/ technical complications were observed in any of the participants.

The marginal integrity of 86.7% and 13.3% of samples were in excellent and acceptable state from baseline to 12 months which further decreased to 82.2% and 17.8% respectively at 18 months (Graph 1). The crowns were assessed for color stability and it was found that 71.1% and 26.7% of samples were in excellent and acceptable state from baseline to 18 months. A discoloration was noted in 2.2 % of samples at baseline(Graph 2). When the surface of the crowns were assessed, it was found that 80% and 20% of samples were in excellent and acceptable state at baseline which decreased to 77.8% at 6 months. About 77.8% and 22.2% remained in excellent and acceptable state from 6 months to 18 months(Graph 3). All samples (100%) maintained excellent anatomic form up to 12 months. However, a slight decline was observed at 12-months, at which point 97.8% of the samples still exhibited excellent anatomic form(Graph 4).

The periodontal health was assessed using Gingival Index. At baseline, 100% of participants had healthy gingiva, and at 6 months, 77.8% had healthy gingiva, while 15.5% and 6.7% had mild to moderate gingival inflammation. After 12 months, 71.2% of samples had healthy gingiva, while 15.5% and 13.3% had mild and moderate gingival inflammation, which remained the same until 18 months.

It was observed that the number of participants with mild to moderate gingival inflammation increased from baseline to 18 months., however, a Cochran's Q test revealed that the distribution lacked statistical significance (P = 0.09) (Table 1).

At 6 months, 100% of participants had probing depths of < 3 mm. At 6 months, 75.6% had probing depth of < 3 mm, while 15.6% and 8.8% had probing depth of < 4 mm and 4 mm to 5 mm. After 12 months, 71.2% of samples had a probing depth of < 3 mm, while

15.5% and 13.3% had probing depths of < 4 mm and 4 to 5 mm, respectively. Similar results were obtained at 18 months.

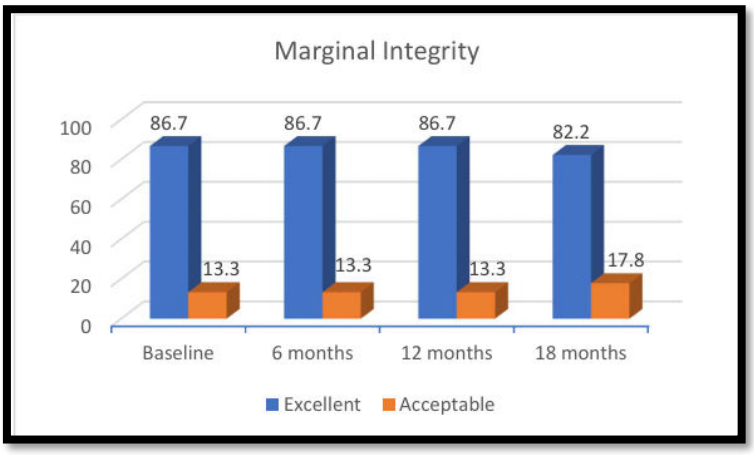
An increase in the number of participants with gingival probing depth of > 3 mm from baseline to 18 months was observed, however, a Cochran's Q test revealed that the distribution lacked statistical significance (P = 0.08) (Table 2).

The wear of the opposing tooth was evaluated at 18 months and it was found that the mean tooth wear of the opposing tooth was 63 µm with a minimum of 0.02 µm and maximum tooth wear of 0.16 µm respectively (Table 3).

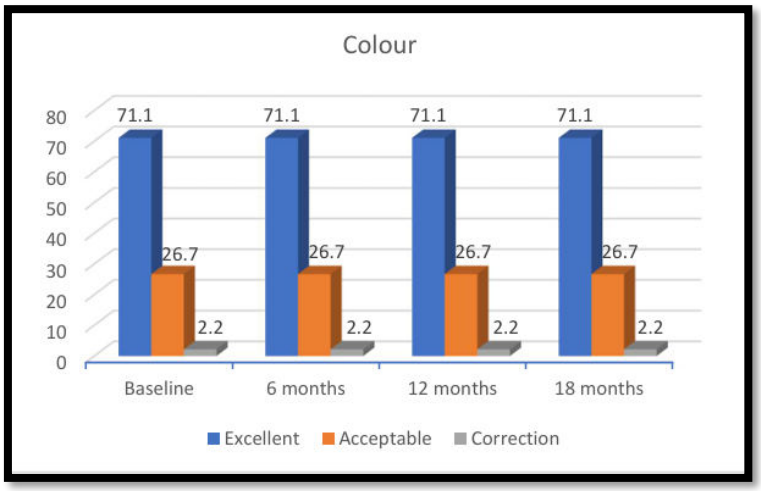
Tooth wear was more from samples in posterior teeth of females than males. However, the difference in mean tooth wear was not statistically significant between males and females (P = 0.4) (Table 4).

The tooth wear was more in maxillary posterior teeth compared to mandibular posterior teeth. However, the difference in mean enamel wear between maxillary and mandibular teeth was not statistically significant (P = 0.19) (Table 5).

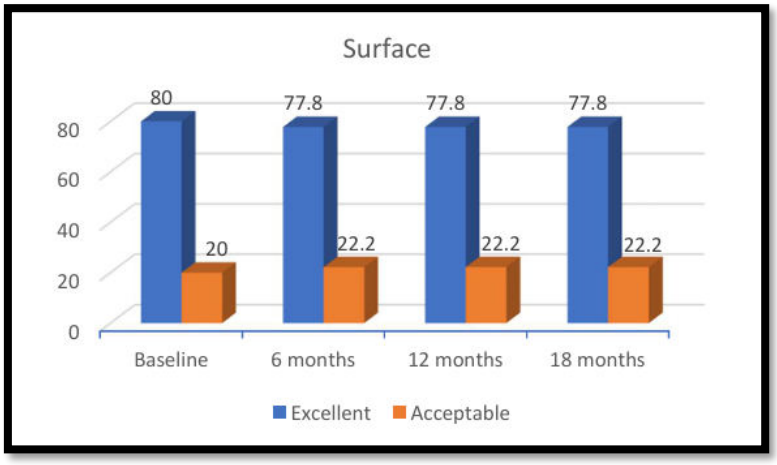
Graph 1: Marginal Integrity of monolithic zirconia crown on posterior teeth



Graph 2: Colour stability of monolithic zirconia crown on posterior teeth



Graph 3: Surface of monolithic zirconium crown on posterior teeth



Graph 4: Anatomic form of monolithic zirconium crown on posterior teeth

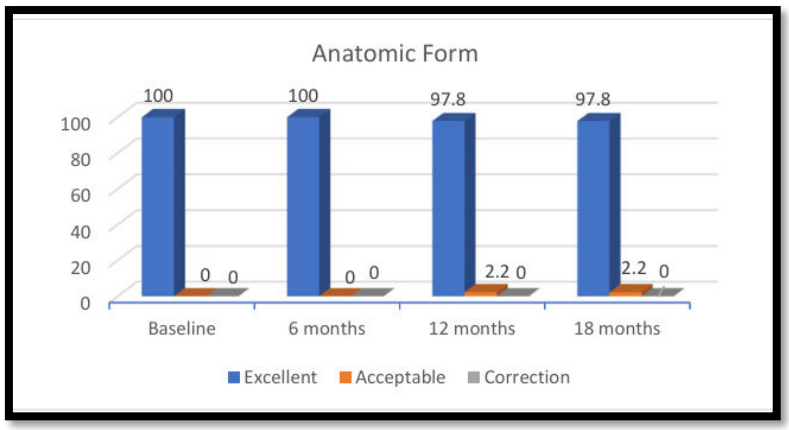


Table 1: Comparison of participants according to the gingival health at different time intervals

	Healthy Gingiva	Mild to moderate inflammation	Cochran's Q	P value
Baseline	45	0	6	P = 0.09 NS
6 Months	35	10		
12 Months	32	13		
18 Months	32	13		

NS-statistically significant using the Cochran's Q test

Table 2: Comparison of participants according to the gingival pocket depth at different time intervals

	Probing depth < 3 mm	probing depth > 3 mm	Cochran's Q	P value
Baseline	45	0	6.75	P = 0.08 NS
6 Months	34	11		
12 Months	32	13		
18 Months	32	13		

NS-not significant using the Cochran's Q test

Table 3: Mean tooth wear of the opposing tooth

Tooth wear	Minimum	2
	Mean ± SD	63 ± 3
	Maximum	16

SD-standard deviation

Table 4: Comparison of mean tooth wear of the opposing tooth according to gender

	Number	Mean	SD	t	P value
Males	25	0.058	0.037	-0.84	P = 0.4
Females	20	0.068	0.032		NS

SD-standard deviation; NS-not significant using unpaired t-test

Table 5: Comparison of mean tooth wear of the opposing tooth according to maxillary and mandibular teeth

	Number	Mean	SD	t	P value
Maxillary teeth	18	0.071	0.04	1.31	P = 0.19
Mandibular teeth	27	0.057	0.02		NS

SD-standard deviation; NS-not significant using unpaired t-test

Discussion

The objective of the study was to assess the clinical performance of monolithic zirconia posterior crowns and to assess the wear of the opposing tooth during a 18 month follow up. The results of the present study confirm the acceptance of the null hypothesis, as no significant differences were found in the quality, periodontal parameters of monolithic zirconia crowns, or the wear of the antagonist tooth between baseline and follow-up periods. In this prospective study, no complications such as crown fractures, loss of tooth, loss of retention and loss of opposing teeth were noted, resulting in a higher survival rate.

The quality of Monolithic Zirconia crowns was assessed using the modified CDA quality evaluation system and all crowns were in an excellent or acceptable range with the exception of one crown which showed a colour mismatch at baseline.

At follow up evaluation, no secondary caries was detected. This feature attributes to the good marginal adaptation of Zirconia crowns. As the marginal discrepancy increases, a nidus is created for plaque accumulation, loss of attachment, dissolution of the luting cement and ultimately bacterial percolation and secondary caries. Various factors affect the marginal fit, namely, spacer parameter settings in the CAD/CAM software,[13]digitalization, data processing, and production process,[14]and margin preparation design.[4,15] Batson et al in 2014 compared the marginal fit between 3 crowns and reported superior results in zirconia crowns in relation to metal ceramic and lithium disilicate crowns.[16]

All crowns showed excellent and acceptable results for colour evaluation, with the exception of one crown which showed a slight mismatch in comparison with the adjacent tooth at the time of cementation. This is primarily due to the nature of monolithic zirconia restorations, which initially appear as chalky white blocks with low translucency.[17] Studies by Heffernan et al.[18] and Chen et al.[19] have shown that zirconia is the least translucent among all all-ceramic materials. Additionally, surface texture influences ceramic translucency; Uhlmann et al.[20] noted that a highly polished, glossy

surface reflects light at an angle equal to the angleof incidence, resulting in specular reflection. In response, higher translucent zirconia millable materials have been developed, featuring shaded gradations and varying opacities to enhance their esthetic appeal.[17]

The Zirconia crowns showed no change in surface texture when assessed at 6, 12 and 18 months. However, they demonstrated a slight increase in surface roughness when compared to baseline data. Several determinants have been investigated to affect surface texture namely, abrasion, wear and brushing.[5, 21]In an intro study, Amer et al subjected 3 types of ceramics to simulated mastication cycles, and reported that Y-TZP and lithium disilicate exhibited lower surface roughnesscompared to conventional feldspathic porcelain.[21]

All crowns exhibited anatomic forms within the excellent to acceptable range, reflecting well-contoured restorations that were in harmony with adjacent teeth and surrounding soft tissues.

In the present study, the gingival index and pocket probing depth levels increased at 6 months and remained consistent till 18 months follow up. Sola Ruiz et al found a significant increase in Bleeding on probing around rehabilitated teeth when evaluated after 5 years.[1] Similarly, Konstantinidis et al found a significant increase in BOP scores around the crown.[5]

The findings differ from the results obtained in a study conducted by Mikeli et al, where the BOP and Pocket Probing Depth values of zirconia crowns remained stable over 3 years after cementation.[2] Similarly, Tang et al. reported comparable results in a study where periodontal parameters of the crowns were assessed against those of the antagonist teeth, contralateral counterparts, and the antagonists of those contralateral teeth over a 96-week period. No significant differences in periodontal parameters were observed at any time point.[6]

An increase in periodontal parameters found in the current study may be attributed to inadequate oral hygiene maintenance by the patient. Paniz et al. and Gemalnaz et al. assessed the correlation between increased BOP values and subgingival margins of crowns.[22,23]

Various factors affecting the periodontal response to the prosthesis include the location of the margin, type of margin preparation, contour of the crown, emergence profile and the surface texture of the crown. Rough and irregular surfaces increase the potential for bacterial accumulation and periodontal breakdown around the restoration.

In the current study, the polished occlusal surface of monolithic zirconia crowns induced a mean wear of 63 ± 3 µm of the antagonist teeth, within reported clinical ranges.[24] Sola Ruiz et al. conducted a meta-analysis and reported that the vertical wear of tooth opposing zirconia crowns ranged from 51.9 µm to 204 µm over 6 to 24 months.[24] Hartkamp et al. investigated antagonist wear from polished zirconia crowns and found a mean maximum vertical enamel loss of 115 ± 71 µm over a 24-month period.[25] Esquivel et al. studied the wear of enamel opposing polished monolithic zirconia crowns and reported a mean maximum vertical enamel loss to be 70.3 4 µm.[26]

There are numerous invitro studies stating that polished zirconia crowns result in less enamel wear compared to glazed zirconia.[27,28] Similarly, Kim et al. reported that polished zirconiaresulted in less enamel wear in comparison toheat-pressed ceramics and feldspathic porcelain.[29]Esquivel et al. found that the wear caused by both monolithic zirconia and metal-ceramic crowns is comparable with no significant wear of antagonistic enamel.[26]Sola Ruiz et al. measured the mean wear to natural antagonist teeth to be 131 ± 27.8 µm and greater than the mean wear to restorations which was 52.7 ± 19.2 µm at 5years.[1]

In contrast, in an invitro study conducted by Beuer et al, they concluded that polished full contour crowns demonstrated significantly less wear of the crown and higher wear of the antagonist tooth when compared with other zirconia study groups.[30]

A vast number of studies have proved that a smoother surface was created by polished zirconia when compared to glazed zirconia, thereby being less abrasive to the antagonist enamel. The increased wear seen in glazed restorations is mainly attributed to the glaze wearing away with time, leaving a rough surface, accentuating the wear on the antagonist tooth.

The present study also observed greater wear in posterior teeth of females compared to males. Similarly, the tooth wear was higher in maxillary posterior teeth than in mandibular posterior teeth.

The shortcomings of the present study were the relatively small number of participants, limitedfollow-up duration and the absence of a control group. The recent innovations in monolithic zirconia material available, coupled with the dentist's knowledge and the technician's skills, can help in achieving restorations that meet both functional and esthetic desires of the patient. The results of this study suggests that monolithic zirconia can be an effective option for rehabilitation of posterior teeth, as an alternate to conventional metal ceramic restoration.

Conclusion

Taking into consideration the limitation of this interventional study, the following conclusions were drawn:

- No mechanical/biologic failures were recorded in monolithic zirconia crowns after 18 months.
- According to the modified California Dental Association Quality Evaluation System, all crowns exhibited excellent clinical outcomes.
- The crowns exhibited an increase in Gingival Index (GI) and Pocket Probing Depth (PPD) at the 6-month evaluation, with these values maintaining stability across all subsequent follow-up periods.
- At 18 months, the mean antagonist tooth wear was within reported clinical ranges.

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