Academic Dissertation

ENAMEL WEAR CAUSED BY MONOLITHIC ZIRCONIA CROWNS FOLLOWING THREE MONTHS OF CLINICAL USE

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ABSTRACT

To compare the amount of tooth wear induced by monolithic zirconia crown restorations placed in the posterior region with natural tooth wear on the contralateral side. Twenty-five patients in need of single crown restoration were included in this study. Crown preparation was performed according to clinically indicated guidelines, and definitive crown impressions were obtained using PVS material. Gypsum master cast models were fabricated, and single crown dies were sectioned. Crowns were milled using a CAD-CAM procedure from monolithic zirconia blocks, Prettau Anterior Multistratum (ZirconZahn, South Tirol, Italy), by the ZirconZahn method. The crowns were cemented and adapted intraorally. An impression was obtained immediately following crown insertion of both dental arches. Following three months of functional loading, the patients were recalled to obtain a second impression using the same procedure. The cast models were then optically scanned using a lab scanner (ZirconZahn S600 Arti scanner), and the resulting 3D surfaces were exported in STL file format and imported into CloudCompare reverse engineering software for analysis. The zirconia crown antagonists, as well as the contralateral tooth antagonists for all 25 cases, were segmented, and tooth wear was assessed as the negative space (wear surface difference) between the two surfaces. The root mean square (RMS) surface difference in millimeters between the two impressions was quantified. The resulting tooth wear was quantified in an Excel sheet and saved for statistical analysis. All patients presented for recall with no dropouts. SPSS statistical analysis software was used for analysis. Mean tooth wear of the zirconia crown antagonist was (10µm±1.05µm) and in the contralateral was (8µm±1.4µm) following three months of functional loading, and the differences were statistically significant at P=0.48. No crowns were lost, chipped, or dislodged at the follow-up visit. Within the limitations and the short follow-up period of this study, it can be concluded that tooth wear induced by monolithic zirconia restoration did not differ from naturally induced wear on the contralateral side. Further research is needed to corroborate the findings of this investigation.

KEYWORDS: *tooth wear, monolithic zirconia, dentistry, lab scanner, three-dimensional models*

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INTRODUCTION

Zirconia ceramics, which meet the demands of patients and dentists for a metal-free, tooth-coloured, and biocompatible restorative material, are increasingly used in prosthetic dentistry. Clinical success of zirconia-based crowns and fixed dental prostheses has been demonstrated by several studies (1, 2). High-strength zirconia is generally layered with veneering porcelain, which is prone to fracture due to a weak interface. Therefore, zirconia-fixed dental prostheses without veneering ceramic, known as monolithic zirconia reconstructions, are currently popular. Advantages of using these crowns include a conservative preparation, as there is no need to maintain space for the veneer porcelain. Additionally, the technique-sensitive procedure of veneering is also eliminated. Monolithic zirconia crowns can be polished using various techniques or glazed before definitive cementation (3, 4). However, various authors have recommended the use of polished zirconia as it causes less wear of the antagonist enamel under in vitro conditions. (3, 5-7). On the other hand, the increasing application of monolithic zirconia in dental applications raises questions such as tooth colour reproduction, long-term chemical stability, final surface state, and wear behaviour (8). In addition, chipping has been reported to be a major complication due to the superior hardness of zirconia surfaces (Hv≈1200 GPa), which is roughly double that of porcelain, leading to concerns that excessive wear to the antagonists has been raised (9-12).

Loss of tooth structure is most prominently seen in the form of carious lesions. Yet, with caries prevalence declining thanks to the introduction of fluoride-containing toothpastes, an increased interest in loss of tooth substance through another process, tooth wear, has emerged. In a physiological situation, the degree of annual vertical tooth wear rarely exceeds 50 µm (3, 5, 13), but it tends to progress with age. Tooth wear is a multi-factorial condition, which can be classified based on the underlying etiology into attrition, abrasion, abfraction, and erosion. It is important to recognize tooth wear to distinguish between pathological and physiological wear, which indicates the need for treatment. However, tracing tooth wear is only possible if the loss of tooth structure is visible to the practitioner, which is not always the case. The clinically employed indices are limited in their ability to monitor tooth wear progression in early or moderate stages since the amount of tooth substance loss is not readily visible to the practitioner (8). Therefore, alternative techniques for quantifying early tooth wear have been proposed. Techniques relying on digitizing the patient's dental casts have been previously described (6, 7).

In vitro studies have shown that antagonist wear rates are significantly dependent on the surface texture of zirconia materials (14, 15). Glazed zirconia seems to cause greater antagonist wear than polished zirconia (15, 16).

The aim of this clinical study is to quantify the enamel wear caused by glazed monolithic zirconia to the antagonist crown following three months of occlusal load and to compare the wear of two natural contralateral antagonists on the same patient. The null hypothesis was that glazed monolithic zirconia crowns and natural teeth cause comparable wear of opposed enamel under similar clinical conditions.

MATERIALS AND METHODS

This prospective clinical trial was approved by the local clinical investigation's ethics Committee, Kosovo Dental Chamber, Nr 001.

All participants gave informed consent. The study was conducted in accordance with the Declaration of Helsinki and the principles of Good Clinical Practice (GCP). A total of twenty-five patients were included in this project. The average age was 27, ranging from 18 to 45 years, with 13 males and 12 females, 23 premolars and 2 molars. Inclusion criteria consisted of:

- ≥ 18 years of age;
- medical indication for a crown;
- no systemic or local conditions presenting a contraindication for a crown;
- need a natural (not crowned) opposing antagonist and two natural (not crowned) contralateral antagonistic teeth;
- teeth with fillings were allowed if at least one occlusal contact point was enamel;
- smoking < 20 cigarettes/day.

Potential subjects who met any of the following criteria were excluded from participation in this study:

- missing occlusal contact points on the enamel of the contralateral antagonists;
- patients showing any signs of developmental enamel defects, fluorosis, parafunctional habits, temporomandibular joint disorder, calcium metabolic disorders, or osteoporosis will be excluded from the study;
- poor motivation;
- inability to sign an informed consent.

Tooth preparation

Teeth were treated, twelve in the upper jaw and thirteen in the lower jaw. Chamfer finish lines were prepared with a circumferential reduction of the tooth substance between 1 and 1.5 mm, in accordance with the remaining hard tissue. The preparation margin was placed at a gingival level whenever possible, and in any case, not exceeding 1 mm of subgingival depth. All internal edges were rounded. The preparation's divergence angle was approximately 6° (17-18).

After tooth preparation, a provisional restoration was placed using a temporary resin-based material (LuxatempTM Crown, DMG Dental Milestones Guaranteed, Hamburg, Germany). The patients were then scheduled for the final adjustment of the preparation and polishing.

Impression technique and crown fabrication procedure

A double cord technique was used to allow a correct display of the finish line for the final impression (Best Cord #000 and Best Cord #00; PPH Cerkamed, Stalowa Wola, Poland). A disposable soft tissue retractor (Optragate; Ivoclar Vivadent, Schaan, Liechtenstein) was placed to retract the lips and the cheeks. For final impressions, a vinyl polysiloxane (VPS) material was used (Elite PP Putty and Light Body Zermack, Rovigo, Italy) in standard rigid plastic trays (Directed Flow Impressions Tray, 3M ESPE, Seefeld, Germany) (Fig. 1).

Fig. 1. *Definitive impression with silicone.*

The antagonist arch impression was taken using the same material, and the bite was registered with Voco Registrado Clear (Voco, Cuxhaven, Germany), which was then sent to the participating laboratory. Working casts of type IV gypsum, Sherahardrock (Shera, Lemfcorde, Germany), were subsequently made. The crowns were made of high, translucent zirconia Prettau Anterior Multistratum (ZirconZahn, South Tirol, Italy) by the ZirconZahn method, that is, fabrication of non-veneered, monolithic crowns by first 3D scanning of the working casts and working dies (ZirconZahn S600 Arti scanner)

The design of the dental restoration was performed by the technician using CAD/CAM software (EXOCAD Design Software). The digitally adjusted data was transferred to a milling machine (ZirconZahn M1), which then cut the zirconia crown to its final form. After the milling process, the crowns were adapted, and the occlusal surfaces were characterized with fine-diamond burs before sintering (Edenta, Au, Switzerland). The crowns were sintered at 1500°C, resulting in shorter sintering times for 3 h in a high-temperature sinter furnace (Zirconzahn S300). After sintering, the crowns, particularly the occlusal surfaces, were polished using the Zirconia Polisher Wheel Pink from Zirconzahn. After polishing, the crowns were glazed with a glaze recommended by the manufacturer, Zirconzahn Glaze Plus. They were then stained and characterised using shading pastes (Zenostar Color Zr) to match the natural tooth colour. Crowns were then stained with ICE 3D Stains by Enrique Steger. In the end, firing of the glaze at 850 °C for 2 min (Ivoamat 2500**) completed the manufacturing process in a laboratory (Fig. 2).

Fig. 2. *Crown stained with ICE 3D stains by Eneique Steger.*

Cementation procedure

After receiving the crowns in the clinic, occlusion, aesthetics, and perfect fit were checked. If necessary, the occlusion was adjusted, and the crown was returned after occlusal adjustment with a fine bur (Edenta, Au, Switzerland) for glazing. Before permanent cementation, the abutment tooth was cleaned with Tubulitec (GP Dental Sweden). Permanent cementation was made with glass-ionomer cement Fuji Plus (GcEurope, Leuven, Belgium) (Fig. 3).

Fig. 3. *Crown after permanent cementation.*

After permanent cementation,0-3 days for tooth wear analysis, another impression was taken with a vinyl polysiloxane (VPS) (Elite PP Putty and Light Body Zermack, Rovigo, Italy), than cast from gypsum and 3D scanning of casts was similar to the procedure followed for crown manufacturing (ZiconZahn S600 Arti Scanner) (Fig. 4). Three months following functional loading, a second impression was taken using the same protocol like in the first impression.

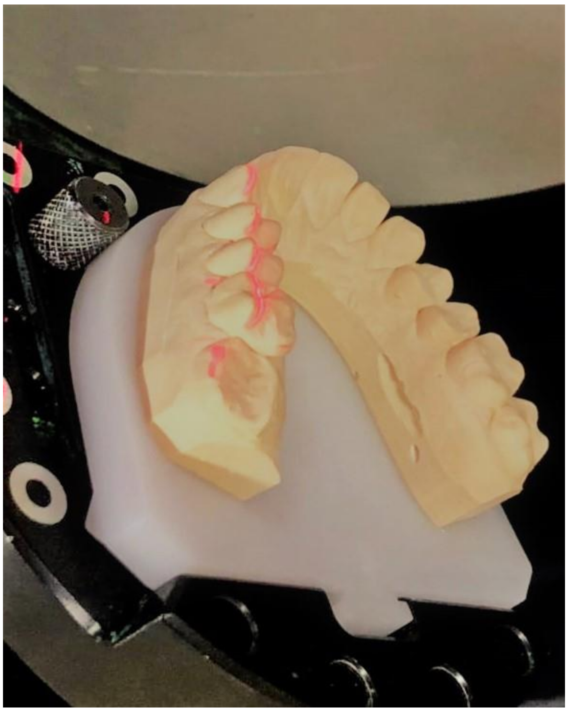

Fig. 4. *Scanning of the working casts.*

Data analysis

The scanned STL files were imported into CloudCompare software for analysis. At first, the 3D models were checked for artifacts. All surfaces were then superimposed and aligned using software tools. The iterative closest point (ICP) algorithm was used to superimpose the two surfaces. The ICP algorithm calibrates a rigid transformation matrix consisting of three rotation and three translation parameters (19). Fig. 5 demonstrates the import procedure of the STL model into the reverse engineering software.

Fig. 6 demonstrates the matching procedure of initial rough alignment of the two surfaces and Fig. 7 alignment after cropping of the block and Fig. 8 matching results of comparison pairs limited only to the teeth and Fig. 9 show fine aline, the alignment results (surface distance measurements)The mean distance was measured through the software between each step of simulated tooth wear using the sound original tooth as reference.

Fig.10 shows automatically generated results after fine alignment, presented to us: minimum distance, maximum distance, average distance, sigma, and maximum error (Fig. 5-10).

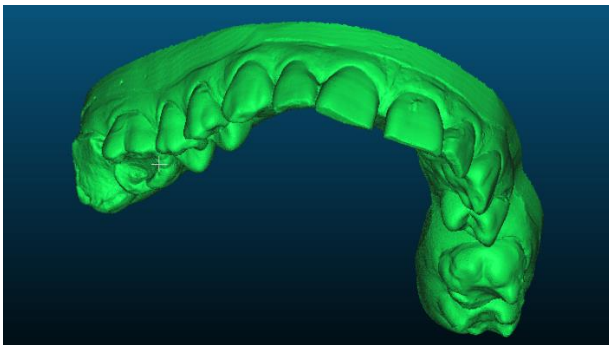

Fig. 5. *Import procedure of the STL model into software.*

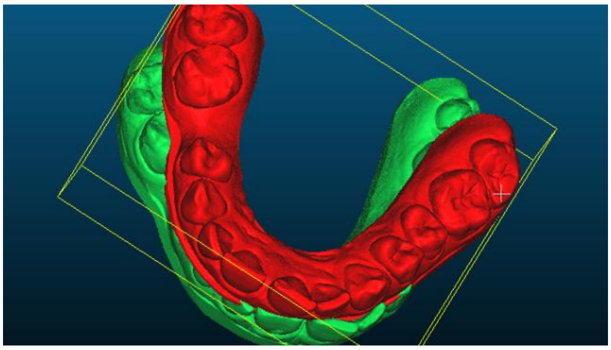

Fig. 6. *The two models (immediately post-cementation at 3-month follow-up).*

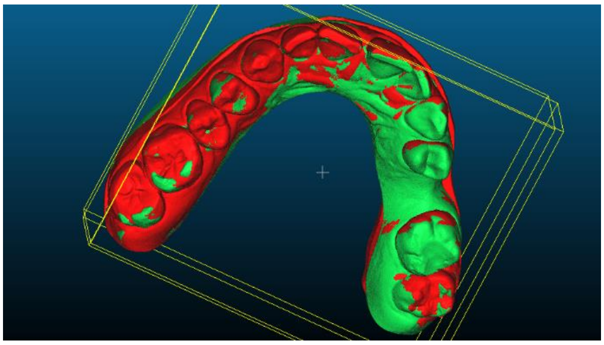

Fig. 7. *Rough alignment of the models.*

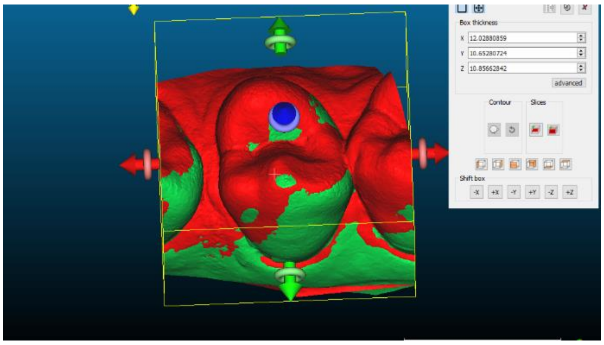

Fig. 8. *Definitive alignment after model cropping.*

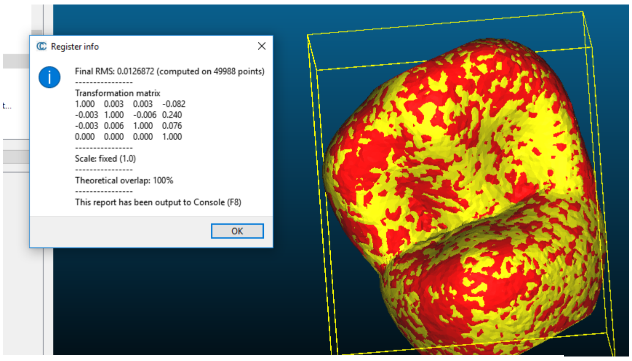

Fig. 9. *The alignment results (surface distance measurements).*

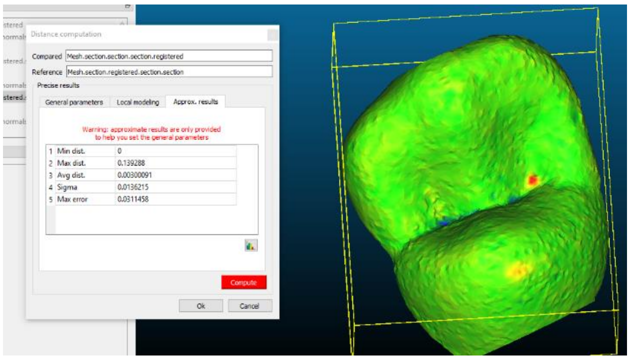

Fig. 10. *Occlusal cusp-fossa contact of the antagonist.*

RESULTS

Data was analyzed in SPSS (PASW Statistics v. 18 for Windows, SPSS Inc., Chicago, IL). Descriptive statistics of the mean average distance were calculated for each comparison pair.

Precision of the scanning procedure was calculated as the mean distance between repeated scans for each tooth. All patients presented for recall with no dropouts. SPSS statistical analysis software was used for analysis. Mean tooth wear of the zirconia crown antagonist was (10µm±1.05µm) and (8µm±1.4µm) following three months of functional loading, and the differences were statistically significant at P=0.48. No crowns were lost, chipped, or decemented at the follow-up visit (Table I).

Table I. *Follow-up visit.*

Patient nr.	Name (I	Age	Gend	Tooth	Min. Dist.	Min. Dist	Max. Dist.		Avg. Dist.		Sigma		Max error	
					Antag.	Contr.	Antag.	Contr.	Antag.	Contr.	Antag.	Contr.	Antag.	Contr.
1	A.B.	25	F	35	0	0	0.222	0.063	0.009	0.003	0.027	0.012	0.024	0.022
2	A. SH.	18	F	25	0	0	0.188	0.116	0.011	0.005	0.027	0.016	0.028	0.025
3	B. SH.	18	M	35	0	0	0.121	0.191	0.005	0.004	0.018	0.018	0.027	0.028
4	M. Z.	25	F	46	0	0	0.202	0.182	0.004	0.003	0.02	0.015	0.041	0.041
5	I.M.	29	F	34	0	0	0.215	0.079	0.004	0.002	0.019	0.011	0.024	0.028
6	B.M.	32	F	44	0	0	0.155	0.144	0.011	0.003	0.024	0.014	0.025	0.022
7	F. SH.	21	M	14	0	0	0.122	0.198	0.004	0.007	0.015	0.021	0.025	0.027
8	SH. B.	20	M	14	0	0	0.198	0.141	0.021	0.004	0.031	0.017	0.024	0.028
9	E. B.	25	F	25	0	0	0.203	0.353	0.009	0.037	0.028	0.053	0.028	0.025
10	F.M.	36	M	15	0	0	0.297	0.182	0.012	0.006	0.028	0.021	0.029	0.025
11	A.G.	24	F	24	0	0	0.278	0.173	0.011	0.008	0.029	0.022	0.025	0.022
12	V.RR.	21	M	44	0	0	0.233	0.252	0.018	0.013	0.039	0.031	0.031	0.031
13	N.A.	22	F	24	0	0	0.231	0.156	0.012	0.008	0.032	0.021	0.025	0.023
14	B.Z	45	M	45	0	0	0.102	0.198	0.008	0.006	0.021	0.021	0.029	0.029
15	F.U.	35	M	15	0	0	0.185	0.186	0.007	0.008	0.023	0.021	0.024	0.026
16	S.H.	38	F	34	0	0	0.262	0.091	0.017	0.006	0.044	0.016	0.031	0.026
17	L.Z.	34	F	24	0	0	0.151	0.111	0.011	0.006	0.022	0.018	0.023	0.024
18	K. O.	21	F	34	0	0	0.198	0.198	0.014	0.009	0.032	0.026	0.029	0.031
19	M. B.	22	F	24	0	0	0.255	0.218	0.024	0.009	0.039	0.024	0.027	0.024
20	G. Y.	30	M	45	0	0	0.096	0.215	0.007	0.006	0.021	0.022	0.034	0.034
21	Y. K.	20	M	36	0	0	0.285	0.111	0.011	0.005	0.033	0.019	0.045	0.039
22	A. D.	21	M	25	0	0	0.218	0.464	0.015	0.023	0.032	0.049	0.031	0.022
23	M. P.	35	M	25	0	0	0.172	0.098	0.006	0.006	0.019	0.017	0.026	0.024
24	K. N.	34	M	35	0	0	0.114	0.112	0.007	0.006	0.016	0.02	0.019	0.025
25	M. B.	26	M	34	0	0	0.131	0.167	0.014	0.007	0.027	0.021	0.029	0.027

DISCUSSION

This study was conducted to evaluate the amount of tooth wear induced by monolithic zirconia restorations and to compare it with the naturally occurring tooth wear on the contralateral side, using an objective computer analysis method to monitor tooth wear progression. The results indicate that tooth wear caused by monolithic zirconia did not exceed the physiological tooth wear rate of 9µm at a similar follow-up period (20). In this study, the second intact tooth on the contralateral side was used as a reference surface. Earlier studies employed models modified for improved reference or used landmarks as a reference (7, 21, 22). This study demonstrates that, for reference, a single sound crown is sufficient as a reference surface during the matching procedure. We expect that even a smaller reference surface, like a small restoration, will be sufficient for a good matching procedure.

Mean average distances calculated are affected by the amount of sound surface, as this surface is considered in the calculation. These values, therefore, do not accurately reflect the extent or location of applied tooth wear. This can be solved by considering the location of dental wear when selecting a region of interest (ROI) prior to calculating surface distance, so that only affected surfaces are included in the average distance calculation. However, due to technical constraints of the software, this approach was not adopted in this investigation. Additionally, the STL files provided by the manufacturer contained artifacts, even though these did not appear after scanning. This might have influenced average distances during calculation. Prior to scanning, the ZirconZhan lab scanner requires the operator to spray a contrast powder on the teeth to negate reflection.

Since spraying is performed manually, it is susceptible to human error, making it difficult to predict the exact thickness of the powder layer. Additionally, after spraying, flakes of powder may sometimes be visible. As the scanning of the surfaces has an accuracy on a micrometer scale, these factors could influence the calculated mean average distance. Not all chair-side optical scanners require the application of a contrast medium.

Previous research has reported similar findings to those of the current investigation. Stober et al. reported 16 µm of tooth wear following 3 months of functional loading (1). They used digital subtraction photography to assess the amount of tooth wear. However, this technique is two-dimensional and does not represent surface topology as precisely as the 3D surface matching technique. Lohbauer et al. reported a maximum vertical tooth surface loss of 200 µm in the antagonist following 2 years of functional loading (12). However, maximum dimensional changes are prone to susceptibility to outliers caused by dimensional changes during the SEM scanning procedure. Mean surface loss values could be significantly lower than the maximum errors and, therefore, of little clinical relevance. In an in vitro investigation by Stripetchdanond et al., monolithic zirconia restoration was found to induce comparable tooth wear to composite resins and less than that of glass ceramics (23).

CONCLUSIONS

Within the limitations of the current study and its short follow-up time, it can be stated that full-prep monolithic zirconium crown restorations on natural abutments exhibit comparable tooth wear to the average annual enamel loss. Further research is needed to corroborate the results of this investigation.

Conflicts of interest

The author declares that there was no conflict of interest. The study was entirely internally funded by the principal investigator, with no external industry funding.

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