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Abrasivity of Yttria Tetragonal Zirconia Polycrystal (Y-TZP) to dental enamel in comparison to Noble White High Palladium alloy

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Abrasivity of Yttria Tetragonal Zirconia Polycrystals

Abstract

Objectives:

To test the wear of enamel against Yttria Tetragonal Zirconia Polycrystals (Y-TZP) in comparison to the wear of enamel against a noble white high Palladium alloy.

Methods:

A total of 20 specimens were used, 10 of Y-TZP and 10 of High Palladium alloy, both were subjected to 202,800 contacts against an enamel rod 2x2 mm in cross section under a mean load of 475.04g leading to a mean force of 4.66 N in a Wilson Wear Machine. The specimens were kept in Dulbecco's phosphate buffered saline at a pH of 7 and the enamel rods were measured before and after the experiment for loss of enamel height (mm).

Results

The mean wear caused by the Y-TZP and the High Palladium alloy tested was 0.0912 mm, and 0.0113 mm respectively. This difference was statistically significant (p = 0.012 ($p<0.05$)).

Significance

It is recommended that Y-TZP is not to be used to form the occlusal surfaces of indirect restorations due to its high abrasive potential with respect to dental enamel.

Keywords:

Abrasivity, Yttria Tetragonal Zirconia Polycrystal, Y-TZP, High Palladium Alloy

Introduction:

The aesthetic demands of patients are such that they are increasingly choosing all ceramic restorations or requesting to change their metal-ceramic restorations to all-ceramic restorations. The reasons given are often aesthetic concerns rather than clinical need. A number of studies [1-5] have reported that certain types of ceramic restorations appear more abrasive than their non-ceramic counterparts, this is potentially of concern for the long term wear of the opposing dentition depending on the patient's occlusal scheme.

An extensive review of the literature was done revealing a number of wear studies involving gold, ceramic and composite. Monasky and Taylor [1] looked at the wear of porcelain, enamel and gold against enamel in a two body abrasion test. Although some details of the study were not provided, specifically the number of samples and the length of the contact track, the results provide for some insight into the relative wear of the materials tested. They reported that porcelain was more abrasive but became less so as continued contact with enamel started to polish the surface and reduce its inherent abrasivity in the longer term. They concluded that porcelain should be finely polished then glazed so as to reduce abrasivity and if the glaze was broken to polish with the finest grain diamond finishing paste available. The use of samples with a flat surface has improved the methodology by reducing sample variability for studies of this type as the wear will be evenly distributed providing for a consistent approach to the interpretation of the results obtained.

Wiley [2] reported a case of tooth surface loss when teeth were opposed by porcelain occlusal surfaces. Although wear was noted, in some cases the patients were bruxists and some of the occlusal surfaces were also adjusted. It was also unclear whether after adjustment the porcelain was polished. These factors make interpretation of the results difficult. Strategic use of gold to help prevent wear was recommended, but it can sometimes be difficult to persuade patients who request that a more aesthetic material is used.

Jacobi and Shillingburg's [3] in vitro study compared the abrasivity of ceramic surfaces versus gold and found gold to be the least abrasive. The cast ceramic was less abrasive then the feldspathic porcelain however if a cast ceramic was shaded or cerammed the abrasivity increased. A tooth cusp, instead of a standardised sample with a flat surface was used in this study, which may have changed the tooth surface area as wear progressed thus introducing a variable that is difficult to control.

Krejci et al [4] carried out a study on the abrasivity of porcelain inlays on opposing tooth enamel. Feldspathic porcelain was reported to be the most abrasive then polished cast glass ceramic followed by polished pressed ceramic. However the degree to which the porcelain was polished to was not fully described, which could have an effect on the degree of wear, and in addition non-standardised samples were used.

Ratledge et al [5] carried out an in vitro study of enamel wear against a number of materials. The least abrasive was amalgam, followed by composite placed as an indirect restoration, enamel, conventional composite, unglazed ceramic with the most abrasive being glazed porcelain. It was shown that in the conventional composite large quartz particles were dislodged, giving rise to 3-body abrasion.

The literature is further confusing as Magne et al [6] showed no statistical difference between polished and glazed porcelain surfaces, which contrasts significantly with the results reported by Monasky et al [1]

Kaidonis et al [7] tested the abrasivity of enamel on enamel in the presence of different fluids including: Dry, Water at pH 7, Citric Acid at pH 3, Hydrochloric Acid at pH 1.2 and Saliva with a pH of 7. Water and saliva showed considerably less wear than hydrochloric acid, however the citric acid exhibited less wear than the water and saliva. This may have been due to the weight loss model used and potentially water was absorbed into the citric acid. This study concluded that pH could affect the wear rate of the materials tested and generally the more acidic the fluid was the more wear was experienced.

A review article by Oh et al [8] discussed some of the factors that cause wear of dental enamel by ceramics. Increased hardness is shown to cause increased wear of enamel, this suggests that even if metal is used, considered to be less abrasive, if it contains cheaper alloys it may be more abrasive. However Seghi et al [9] concluded that there is a poor correlation between the hardness of a material and its potential to abrade enamel.

Frictional resistance is also stated to be a factor in increasing wear by Oh et al [8] and higher forces and speed increased wear. This suggests that parafunction increases wear which is supported by Wiley [2]. Decreased fracture toughness is also thought to increase wear as the resulting chipping would result in a rougher surface and cause more wear as shown by Magne et al [6].

The effect of crystal types within ceramics on wear can be complex. Although wear can be increased by hard crystals, they can also increase the stability of a material making it less likely to fracture [8]. Chemical surface degradation can also increase wear as shown by Lughi et al [10] where Zirconium oxide degrades at low temperature. Occlusal forces have an effect where increased force can cause increased wear as shown by Braun et al [11]. Higher forces are shown to be applied to posterior teeth in comparison to anterior teeth – Kikuchi et al [12].

Various methodologies have been used which have included measuring changes in the weight, height and volume of the material tested. DeLong (13) suggested changes in volume was the preferred method to evaluate wear but requires specific equipment. If weight is used, water can play a significant role due to absorption and dehydration. Consequently changes in height is considered to be the optimal technique as it can be standardised.

Park (14) et al looked at the wear of Zirconia and feldspathic porcelain against enamel, with differing polishing and finishing regimes and reported that the Zirconia tested was significantly less abrasive than the porcelain tested due to its homogenous and uniform character. A similar study by Kim et al (15) reported similar findings. To date no study has compared the abrasivity of zirconia with that of a noble white high palladium alloy. It was the purpose of this study therefore to compare the abrasivity of Yttria Tetragonal Zirconia Polycrystal (Y-TZP) with that of a noble white high palladium alloy.

Materials and methods:

10 specimens of Y-TZP and 10 specimens of a palladium alloy were tested for their wear against dental enamel. The sample size was informed from a review of the literature [15] and a sample size of 10 was considered appropriate for a study of this type.

A Wilson Wear machine (manufactured in house) was used to cause wear in a controlled and dentally relevant way. To do this the machine had 10 stations with each having a material at the bottom, the test material (Y-TZP or High Palladium alloy), and at the top, the antagonist (dental enamel). The test material specimens were covered in Dulbecco's Phosphate Buffered Saline, which was buffered at pH 7. Each station was loaded with a weight held in place with a rod and a positioning device. The enamel sample was encased in Duralay resin in a metal coping and attached to the top member of the Wilson Wear Machine.

In an effort to reduce variability, the weights used at each station in the Wilson wear machine were kept as similar as possible with the mean weight being 475.04 g. Weighted rods with the attached specimen are raised to around 1 mm by the machine and dropped onto the enamel specimen at a gravitational acceleration of 9.8 ms^2. With the equation force (N) = mass (kg) x acceleration (ms^2) the force created in each station can be calculated. The mean force calculated was 4.66 with a range of 0.06. The sample moved back and forth on a track so the enamel is not contacting the same surface. The contact time between sample and test material was 0.2 seconds, which was similar to the contact time reported by Magne [2], the contacts occured at a rate of 2.167 contacts/second. With there being 202,800 contacts per specimen this led to a total wear time of 40,560 seconds (11.27 hours).. An oscillating motion in the Dulbecco's phosphate buffered saline was created so that debris was flushed from the test surface.

Molar tooth samples from the Human Skeletal Tissue Bank at Leeds Dental Institute were obtained (application number: 030511/KC/66). They were kept in saline and refrigerated, however before use they were disinfected with Virkon disinfectant (a multi purpose disinfectant containing Oxone, Sodium Dodecylbenzenesulfonate, sulphamic acid and inorganic buffers) for 15 minutes, the acidity of which was countered by immersing the samples in Dulbecco's phosphate buffered saline.

A Struers Accutom-5 machine (Struers Unit 11 Evolution @ the AMP, Whittle Way, Catcliffe, Rotherham, S60 5BL) was used to section the teeth into square (2 mm^2)rods with enamel at the tip to give 18 samples per tooth (Fig.1). The flattest surfaces with least decalifications and imperfections were chosen. Sample surfaces were flattened using silicone carbide paper with water as a lubricant. A stainless steel coping filled with Duralay resin (Reliance Dental Mfg.Co, PO Box 38 7560 Worth, IL 60482 USA) held the samples with the enamel surface parallel to the coping base measured using calipers.

Enamel specimen heights were measured from the base of the specimen to the external surface enamel using a micrometer (Mitutoyo Micrometer Series 193-111, Mitutoyo, Japan) calibrated to 0 at room temperature, 3 measurements were taken and if not within +/- 0.002 mm they were repeated.

The high palladium alloy used was Cerapall 2 containing 78.50% Palladium by mass and 2% gold content. The lost wax technique was used to create the samples, which were highly polished to mimic clinical reality. In all 5 samples were used with both sides of the sample used to provide for 10 test surfaces.

Zirconium was obtained from a commercial supplier (Wright Cottrell, Dundee, Scotland) and the zirconium samples were sintered by Wright Cottrell with the degree of shrinkage being taken into account when preparing the samples. Samples were prepared measuring 35 x 16 x 1 mm so as to fit the Wilson wear machine.

The samples were tested in 2 sequences with the palladium alloy and Zirconium being tested simultaneously. The high palladium alloys were then reversed for the second stage of the experiment with new zirconium alloy samples being used. All samples were set up in both runs of the experiment as shown in the tables. The zirconium samples were attached to the lower member of the wear machine. A 1mm space was placed between the tightening pin and machine to allow the upper guide pin to move down by 1 mm. Dulbecco's phosphate buffered saline was then poured into the lower chamber of the machine. The machine was kept running for 26 hours resulting in 202800 contacts between each enamel and test material samples. The samples were then measured using the same procedure as described previously.

Results

The full data set is summarized in Table 1 and this was analysed using statistical analysis software PASW statistics 17.0 (spss.com) and an independent t test was also carried out.

The mean wear caused by Y-TZP was 0.0912 mm, the mean wear of the high palladium alloy was 0.0113 mm. The independent t-test gave a p value of 0.012 demonstrating a significant difference ($p<0.05$) and the 95% confidence interval did not contain the value 0.

Discussion

This study has provided a valuable insight into an area that has previously not been investigated in great detail. The results were shown to be statistically significant and therefore demonstrating that the zirconium tested was significantly more abrasive to enamel than the high palladium alloy tested in this study.

From a clinical view the number of contacts can equate to around 3.8 months of a restoration in function. The expected wear that could be predicted over 10 years with Y-TZP could be 3.95 mm however if the High palladium alloy tested were used it would be only of the order of 0.44 mm over 10 years.

The study has some similarity to a study by Krejci et al (4), which assessed wear of enamel against feldspathic porcelain and a pressed glass ceramic under a 49 N load for 1,200,000 cycles under ageing conditions. Wear was checked at 240,000 cycles again similar to this study and showed feldpathic porcelain to have an average wear of 0.0825 mm close to the 0.0912 mm of Y-TZP found in this study. Comparison of the results of these two studies suggests that Y-TZP is more abrasive than feldspathic porcelain. In addition the results of this study suggest that occlusal surfaces formed out of Y-TZP should be avoided when restorations are being produced due to the abrasivity of the material. Veneering with a less abrasive ceramic material and making sure occlusal adjustments will not expose the underlying Y-TZP is therefore advised. As a consequence more reduction of prepared teeth maybe advisable, which is an important clinical consideration when prescribing restorations of the type described.

The limitations of this study include the relatively low force used, 4 N, in comparison to 200-800 N experienced in the mouth. However it is likely that the abrasion that would occur in clinical service would be significantly higher. Despite this limitation the study allows us to rank the abrasivity of the two materials tested. Further research is needed however to determine the abrasivity of these materials at loads that more accurately represent the level of loading that a restoration would experience clinically. The enamel samples had a 2x2 mm cross section which is not equivalent to the shape of teeth in the mouth however this limitation applied to both groups and therefore again its allows the abrasivity of the materials tested to be compared.

Gold is considered to be the best choice for the formation of the occlusal surfaces of full coverage restorations and this is supported by a paper by Hacker et al (17). However it is unaesthetic and the material is liable to creep and deformation in clinical service. The demands of patients are such that clinicians will have to prescribe more aesthetic type restorations and the priority going forward is to limit the risks that prescription of such restorations involves. If practitioners can educate patients regarding material choices then the high palladium – Au-Cu-In-GA alloy tested has the potential to be a better option for occlusal surfaces with less wear likely to occur. This material has also shown to have good bond to porcelain and is very hard with good castability and corrosion resisitance.

Given that Kou et al [18] reported that after reviewing high resolution images of zirconia before and after polishing it was shown to be significantly smoother. This potentially could have an effect on the wear such a material might cause and further research is needed to establish this.

Conclusions

It was concluded that within the limitations of the study that the abrasivity of the Zirconia (Y-TZP) material tested is significantly greater than the control material in this case a noble white high palladium alloy. It is recommended that care is exercised when Y-TZP is used to form the occlusal surfaces of restorations due to its potential high abrasivity with respect to dental enamel.

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References

1. Monasky GE, Taylor DF. Studies on the wear of porcelain, enamel, and gold. J Prosthet Dent. 1971 Mar;25(3):299-306.
2. Wiley MG. Effects of porcelain on occluding surfaces of restored teeth. J Prosthet Dent. 1989 Feb;61(2):133-7.
3. Jacobi R, Shillingburg HT, Jr., Duncanson MG, Jr. A comparison of the abrasiveness of six ceramic surfaces and gold. J Prosthet Dent. 1991 Sep;66(3):303-9.
4. Krejci I, Lutz F, Reimer M, Heinzmann JL. Wear of ceramic inlays, their enamel antagonists, and luting cements. J Prosthet Dent. 1993 Apr;69(4):425-30.
5. Ratledge DK, Smith BG, Wilson RF. The effect of restorative materials on the wear of human enamel. J Prosthet Dent. 1994 Aug;72(2):194-203.
6. Magne P, Oh WS, Pintado MR, DeLong R. Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent. 1999 Dec;82(6):669-79.
7. Magne P, Oh WS, Pintado MR, DeLong R. Wear of enamel and veneering ceramics after laboratory and chairside finishing procedures. J Prosthet Dent. 1999 Dec;82(6):669-79.
8. Oh WS, Delong R, Anusavice KJ. Factors affecting enamel and ceramic wear: a literature review. J Prosthet Dent. [Review]. 2002 Apr;87(4):451-9.
9. Seghi RR, Rosenstiel SF, Bauer P. Abrasion of human enamel by different dental ceramics in vitro. J Dent Res. 1991 Mar;70(3):221-5.

10. Lughi V, Sergo V. Low temperature degradation -aging- of zirconia: A critical review of the relevant aspects in dentistry. Dent Mater. 2010 Aug;26(8):807-20.
11. Braun S, Bantleon HP, Hnat WP, Freudenthaler JW, Marcotte MR, Johnson BE. A study of bite force, part 1: Relationship to various physical characteristics. Angle Orthod. 1995;65(5):367-72.
12. Kikuchi M, Korioth TW, Hannam AG. The association among occlusal contacts, clenching effort, and bite force distribution in man. J Dent Res. 1997 Jun;76(6):1316-25.
13. DeLong R. Intra-oral restorative materials wear: rethinking the current approaches: how to measure wear. Dent Mater. 2006 Aug;22(8):702-11.
14. Park JH, Park S, Lee K, Yun KD, Lim HP. Antagonistic wear of three CAD/CAM anatomic contour zirconia ceramics. J Prosthet Dent 2014 Jan: 111(1):20-9
15. Kim MJ, Oh SH, Kim JH, Ju SW, Seo DG, Jun SH, Ahn JS, Ryu JJ. Wear evaluation of human enamel opposing different Y-TZP dental ceramics and other porcelains. J Dent 2012 Nov:40 (11):978-88
16. Whitley E, Ball J. Statistics review 4: sample size calculations. Crit Care. 2002 Aug;6(4):335-41.
17. Hacker CH, Wagner WC, Razzoog ME. An in vitro investigation of the wear of enamel on porcelain and gold in saliva. J Prosthet Dent. 1996 Jan;75(1):14-7.
18. Kou W, Molin M, Sjogren G. Surface roughness of five different dental ceramic core materials after grinding and polishing. J Oral Rehabil. 2006 Feb;33(2):117-24.

Figures and Tables

Fig 1: Tooth sectioning technique

Table 1: Data for the pre- and post-test measurements (mm) of the samples

Fig 1: Tooth sectioning technique:

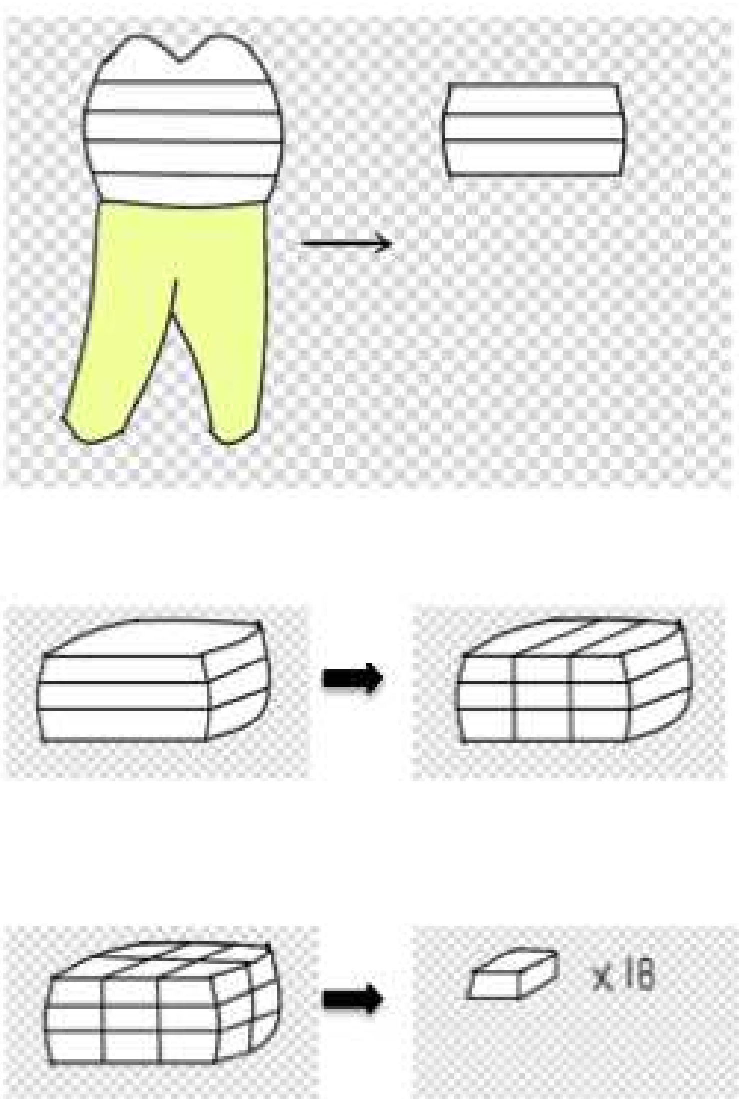

Table 1: Data for the pre- and post-test measurements (mm) of the samples.

Station number	Pre-test Height (mm)	Post-test Height (mm)	Difference (mm)	Group (M=metal, Z=Zirconium)
11	11.284	11.274	0.010	M
12	11.353	11.348	0.005	M
13	11.363	11.238	0.125	Z
14	12.116	12.074	0.042	Z
15	12.334	12.256	0.078	Z
16	12.373	12.368	0.005	M
17	12.093	12.091	0.002	M
18	12.201	12.190	0.011	M
19	12.403	12.316	0.087	Z
110	12.463	12.343	0.120	Z
21	12.030	11.975	0.055	Z
22	12.134	12.067	0.067	Z
23	11.743	11.729	0.014	M
24	11.853	11.853	0.000	M
25	12.546	12.537	0.009	M
26	10.585	10.499	0.086	Z
27	12.569	12.378	0.191	Z
28	11.796	11.735	0.061	Z
29	13.116	13.079	0.037	M
210	11.544	11.524	0.020	M