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One reported advantage of DICOR is a hardness comparable to human enamel. However, DICOR restorations are subjected to different surface treatments as a result of processing, esthetics, and functional requirements. This study compared the Knoop hardness of DICOR specimens under three conditions: Treatment I (cerammed); Treatment II (cerammed and shaded); and Treatment III (sectioned to reveal internal DICOR material).

Knoop hardness differences among groups were statistically significant ($P \leq 0.05$). The cerammed surface was the hardest state of DICOR and harder than human enamel. Shaded DICOR had a surface hardness comparable to dental porcelain. The internal glass-ceramic material, located beneath the shaded porcelain and cerammed "skin," had a Knoop hardness similar to human enamel.

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THE EFFECT OF SURFACE TREATMENT ON THE KNOOP HARDNESS OF DICOR

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Abstract

One advantage cited for the use of DICOR over other ceramic materials is a reported Knoop hardness comparable to human enamel. However when fabricating dental restorations, a DICOR glass-ceramic casting generally is subjected to several different surface treatments because of processing, esthetic, and functional requirements. Therefore, this study compared the Knoop hardness of DICOR specimens under three conditions: Treatment I (cerammed); Treatment II (cerammed & shaded); and Treatment III (sectioned to reveal internal DICOR material). Knoop hardness differences among groups were statistically significant ($P \leq 0.05$). The cerammed surface was the hardest state of DICOR and harder than human enamel. Shaded DICOR specimens had a surface hardness comparable to dental porcelain. However, the internal glass-ceramic material, located beneath the shading porcelain and cerammed "skin," had a Knoop hardness similar to human enamel.

Introduction

Continued interest in esthetic dentistry has sparked the development of new ceramic materials and fabrication techniques. The introduction of a castable glass-ceramic material (DICOR, Dentsply International, Inc, York, PA) has increased the use of full and partial veneer all-ceramic restorations. One of the stated advantages of DICOR over other dental ceramic materials is a reported Knoop hardness (KHN 362)[1,2] which approximates that of human enamel (KHN 343).[3] The implication of such a property is a reduced tendency to wear the opposing dentition compared to conventional dental porcelains.[1,2,4,5] Therefore, this study was undertaken to measure and to compare the Knoop hardness of DICOR following three treatments at different stages in the fabrication process.

Materials and Methods

Initially a pilot study was conducted to measure the Knoop hardness of DICOR, another castable ceramic, Cerapearl (Kyocera America, San Diego, CA), and two feldspathic dental porcelains, Vita VMK 68 (Vident, Baldwin Park, CA) and Optec HSP (Jeneric/Pentron, Inc, Wallingford, CT). The Knoop hardness numbers obtained for the two castable ceramic materials differed markedly from the hardness values reported by the respective manufacturers. In contrast, the feldspathic porcelain results were in agreement with established hardness estimates for dental porcelains.[2,3] During the course of the study, one of the castable ceramic materials (Cerapearl) was reformulated. Consequently, the investigation was refocused and limited to assessing why the DICOR hardness values differed so widely from the manufacturer's reported data.

Five DICOR samples were prepared from wax specimens measuring 12 x 6 x 6 mm by one investigator (CAM). The equipment used in the study had been calibrated and dedicated to the processing of the DICOR castable glass ceramic material.

Once cast, the five specimens were all given the following sequential treatments: Treatment I - cerammed and polished; Treatment II - shaded with four layers of shading porcelain and polished; Treatment III - sectioned and polished. The manufacturer's instructions were followed for all stages of casting, ceramming, and shading.

The five Treatment I specimens were polished after ceramming with a diamond polishing paste (Healthco Porcelain Paste, Healthco Inc., Boston, MA) as the end step. The samples were only polished enough to create a smooth, flat area for microhardness testing with minimal surface disturbance. Ten (10) Knoop hardness measurements were made per specimen.

The Treatment II specimens consisted of the same five Treatment I samples after they were ultrasonically cleaned for 10 minutes in distilled water and then shaded. A total of four layers of DICOR Shading Porcelain (Shade A3.5) were applied to one surface of each specimen. The four layers were individually fired in an Ultra-Mat CDF porcelain furnace (Unitek/3M, Monrovia, CA) to replicate the application of four layers of color to a clinical crown. Once shaded, the colored surface of the specimens was polished, as specified previously, and 10 Knoop hardness measurements were made for each specimen.

For Treatment III, the Treatment II samples were embedded in an autopolymerizing resin (Epoxide Resin, Buehler, Lake Bluff, IL) and sectioned transversely at their midpoint to reveal the internal (parent) DICOR glass-ceramic material (Figure). These specimens were serially polished using 600, 800, and 1000 grit silicon carbide paper and finished with a suspension of 0.5 and 0.03 micrometer aluminum oxide on a cloth wheel.

Knoop hardness measurements were made with a Leco M-400 Microhardness Tester (Leco Corporation, St. Joseph, MI) using a 500-gram load and a 30-sec dwell time. One investigator (WPN) made all the hardness measurements.

A two-way analysis of variance (ANOVA) was conducted followed by a Tukey's Studentized Range Test to determine if the differences in Knoop hardness among the three treatments were statistically significant at the $P \leq 0.05$ level.

Results

Knoop hardness numbers (KHN) for the five polished specimens after ceramming (Treatment I), after ceramming and shading (Treatment II), and after embedding and sectioning to reveal the internal (parent) DICOR material (Treatment III) are presented in Table 1.[6] The structural areas of the DICOR samples that were tested for Knoop hardness are also illustrated in the figure.

The mean Knoop hardness and standard deviation for Treatment I (the cerammed surface) was 505.1 KHN ($\pm$ 23.07); for Treatment II (the shaded surface) it was 446.6 KHN ($\pm$ 22.53); and for Treatment III (the sectioned and polished parent DICOR material), it was 369.4 KHN ($\pm$ 9.67) (Table 1).

The results of the two-way analysis of variance (ANOVA) and Tukey's Studentized Range Test indicated that the observed differences between Knoop hardness and the three treatment conditions were statistically significant ($P \leq 0.05$) for all three groups (Tables 2 and 3).

Discussion

Aside from their excellent esthetics quality, two of the reported advantages for the use of restorations made from the DICOR castable glass-ceramic are Knoop hardness and wear characteristics much closer to enamel than conventional dental porcelains.[1,2,4,5] However, the results of this study indicated that only the polished internal, or parent, DICOR material had a Knoop hardness (KHN 369) which approximated human enamel (KHN 343).[3] Although not often cited, by some estimates the KHN of human enamel may be as low as 300.[7] Furthermore, DICOR specimens veneered with shading porcelain had a Knoop hardness of 447, which is comparable to an autoglazed low-fusing feldspathic porcelain, such as Vita's VMK 68 tested in the pilot study. More important, the Knoop hardness of the cerammed surface of DICOR was 505 which is significantly higher than the parent material, the shaded surface, or human enamel.

Since DICOR was initially introduced, studies have demonstrated greater wear of enamel by glazed or stained DICOR than by the unglazed castable ceramic.[8-10] In addition, DICOR specimens with the cerammed "skin" intact and veneered with shading porcelain were found to be more abrasive than a glazed metal ceramic porcelain, Vita VMK 68.[10] However, polished DICOR specimens, with the cerammed skin removed and no surface colorant (shading porcelain) applied, were reported to be <u>less</u> abrasive (13.4 mg, mean enamel loss) than polished VMK 68 porcelain (26.3 mg, mean enamel loss).[9] Yet, the greatest amount of wear of tooth structure occurred against the cerammed DICOR surface (103.4 mg, mean enamel loss).[10] Given these apparent differences in wear and abrasiveness against human enamel, it has been recommended that DICOR restorations not be glazed in areas of functional occlusion.[8]

More recently, it has been shown that the "skin" or "ceram layer" produced on DICOR restorations after the ceramming process[1,2] may vary in thickness from 25 to 100 micrometers.[11] Contained within that "ceram layer" are what have been described as crystal "whiskers" oriented perpendicular to the external surface.[11] As indicated in the DICOR laboratory manual, the "rod like crystals that form on the surface of the casting during ceramming increase its opacity."[1] Therefore, the outer "skin" may or may not be removed following the ceramming process depending on the level of translucency desired in the final restoration.[1]

Consequently differences in wear data for glazed versus unglazed DICOR and the formation of a "skin" on cerammed restorations, would indicate differences in the microstructure of the castable ceramic material. The high Knoop hardness (KHN 505) of the "ceram layer" found in this study may be attributed to the presence of the crystal "whiskers." [1,2,10] The process of shading DICOR restorations requires the application of a mixture of colorant blended into a porcelain host.[12] Thus, with multiple layers of a low-fusing feldspathic shading porcelain generally needed to achieve satisfactory shade matching, it is logical that the surface hardness of shaded DICOR (KHN 447) would be in the reported range of dental porcelain (KHN 460).[3,7]

Only the internal, or parent, DICOR glass-ceramic material located below the cerammed "skin" had a Knoop hardness (KHN 369) near the upper range of human enamel (KHN 343). Therefore, a shaded DICOR restoration should be viewed as a nonhomogeneous material composed largely of the internal (parent) castable glass-ceramic veneered with a thick, hard cerammed "skin" 25 to 100 micrometers thick or a cerammed "skin" covered with multiple layers of shading porcelain (Figure).

The findings of this investigation, coupled with previously reported wear studies, suggest that the wear characteristics of a DICOR restoration will probably depend more on which part of the glass-ceramic material ("cerammed skin," shaded surface, or parent glass-ceramic material) is actually in contact with human enamel. These differences in Knoop hardness found in this study would indicate that generalities about the favorable wear characteristics of the parent glass-ceramic material may not apply to either cerammed surfaces with the cerammed "skin" intact or cerammed surfaces veneered with shading porcelain.

Conclusions

Based on the results of this study, the following conclusions were drawn:

1. The cerammed and polished DICOR specimens with the "skin" or "cerammed layer" left intact had a mean Knoop hardness of 505 KHN.
2. The DICOR samples that were cerammed and veneered with DICOR shading porcelain had a mean Knoop hardness of 447 KHN, comparable to a metal ceramic porcelain.
3. Only the DICOR specimens that had been sectioned and polished to reveal the internal (parent) glass-ceramic material below the surface "skin" had a mean Knoop hardness (KHN 369) similar to human enamel (KHN 300-343).
4. Differences among the three hardness levels were statistically significant ($P \leq 0.05$).
5. Given the significant differences in Knoop hardness for the three treatments, perhaps the cerammed "skin" should be removed, the areas polished, and left unshaded for those surfaces that are to oppose another restorative material or tooth structure.

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Legends

Figure Cross-sectional view of a test specimen (Treatment III) depicting the layer of shading porcelain placed over the cerammed skin, on the surface of the parent glass-ceramic material.

Tables

Table 1. Knoop Hardness Numbers (KHN) for Different Sample Treatments.

Treatment I - Cerammed:

Specimen 1	507,497,557,558,524,505,474,509,497,556	= 518.4
Specimen 2	501,514,470,418,484,513,494,521,484,533	= 503.2
Specimen 3	517,484,516,502,532,506,504,515,508,496	= 508.0
Specimen 4	496,491,503,519,498,507,502,496,502,494	= 500.8
Specimen 5	516,469,484,520,519,510,530,503,492,509	= 505.2
	Mean (standard deviation)	= 505.1 (± 23.07)

Treatment II - Cerammed and Shaded with 4 Layers of Shading Porcelain:

Specimen 1	466,474,417,441,445,448,488,465,484,498	= 462.6
Specimen 2	411,411,480,445,410,410,443,422,428,478	= 433.8
Specimen 3	466,444,449,453,437,444,479,440,460,438	= 451.0
Specimen 4	438,461,440,429,410,431,426,438,425,442	= 434.0
Specimen 5	476,466,452,450,432,438,481,460,432,431	= 451.8
	Mean (standard deviation)	= 446.6 (± 22.53)

Treatment III - Sectioned Internal, or Parent, Glass-Ceramic Material:

Specimen 1	369,366,358,368,365,357,376,372,351,370	= 365.2
Specimen 2	378,358,365,353,[illegible]33,376,373,374,366,368	= 369.4
Specimen 3	373,372,360,372,350,369,374,366,371,362	= 366.9
Specimen 4	348,373,350,378,377,377,374,368,372,383	= 370.0
Specimen 5	366,369,386,376,388,382,378,368,360,386	= 375.9
	Mean (standard deviation)	= 369.4 (± 9.67)

Table 2. Two-Way Analysis of Variance Data (alpha = 0.05).

Source	df	Sum of squares	Mean square	F value	P
Model	14	473231.77	33802.27	101.00	0.0001
Error	135	45180.60	334.67		
Corrected Total	149	5184112.37			
Specimens	4	5559.91	1389.98	4.15	0.0033
Treatments	2	462863.09	231431.55	691.52	0.0001
Specimens-Treatments	8	4804.77	601.10	1.80	0.0830

Table 3. Tukey's Studentized Range Test (alpha = 0.05)

Grouping	Mean KHN	n	Treatment
A	505	50	Treatment I (cerammed)
B	447	50	Treatment II (cerammed & shaded)
C	369	50	Treatment III (parent material)

The differences among mean Knoop hardness numbers (KHN) for Treatments I, II, and III were all statistically significant ($P \leq 0.05$).

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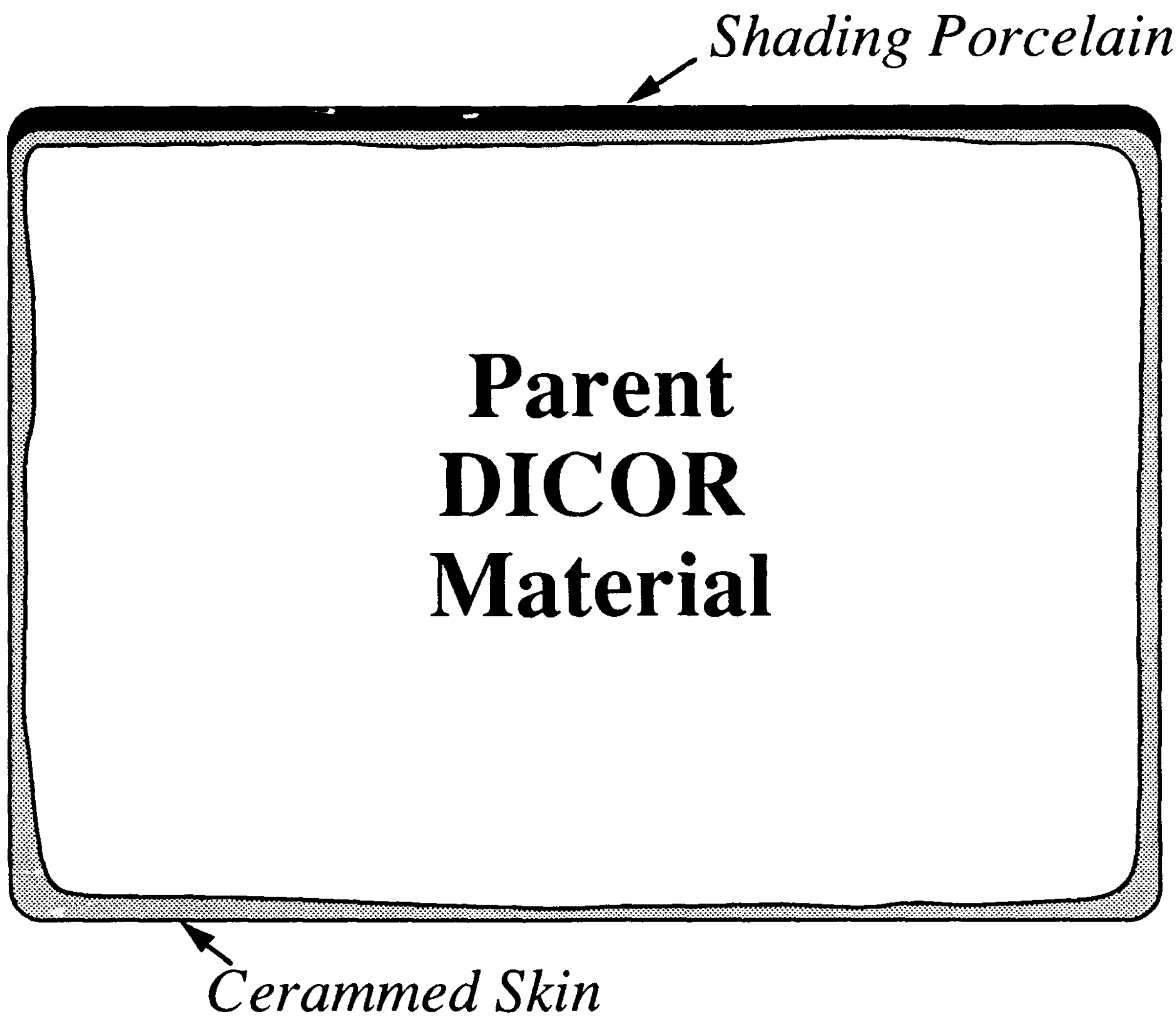
Shading Porcelain
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