



Zirconia Basics and Features of the New Product "KZR-CAD Zr Laxio"

Introducing a new mixed composition layered zirconia beyond the conventional concepts



Index

1. Introduction.....	2
2. Basics of Dental Zirconia	4
2.1. Crystal Structure and Strengthening of Zirconia.....	4
2.2. Dental Zirconia Specifications	5
3. Features of "KZR-CAD Zr Laxio"	6
3.1. Material design	6
3.2. Aesthetics.....	6
3.3. Transmittance	7
3.4. Shielding	8
3.5. Strength	10
3.6. Chipping Resistance	11
3.7. Summary of Laxio Features	12
4. Conclusion	13

Supervision

YAMAKIN Ph. D. Group

Dr. Teruo Anraku (Ph.D. in Engineering)

Dr. Hiroyuki Itoigawa (Ph.D. in Science)

Dr. Takahiro Kato (Ph.D. in Engineering)

Dr. Takeshi Sakamoto (Ph.D. in Pharmaceutical Science)

Dr. Yuji Sato (Ph.D. in Entrepreneurial Engineering)

Dr. Hidekazu Tanaka (Ph.D. in Engineering)

Dr. Ritaro Matsuura (Ph.D. in Agriculture)

Dr. Yusuke Mizuta (Ph.D. in Engineering)

Dr. Shingo Mizobuchi (Ph.D. in Engineering)

Dr. Masatoshi Yamazoe (Ph.D. in Dentistry)

Dr. Hirohisa Yamamoto (Ph.D. in Entrepreneurial Engineering)

Advisor of YAMAKIN Ph.D. Group

Dr. Bunichiro Yamada (Ph.D. in Engineering)

Dr. Tetsuya Yamamoto (Ph.D. in Medicine)

What is the YAMAKIN Ph.D. Group?

This is a group of experts in various specialized fields who bring together their knowledge, experience and technical expertise to act as a prime motivator in the continuous generation of innovation.

Zirconia Basics and Features of the New Product "KZR-CAD Zr Laxio"

Hidekazu Tanaka, Ph.D. (Engineering), Senior Researcher, Inorganic Materials Development Division,
Development Department
Masatoshi Yamazoe, Ph.D. (Dental Science), Senior Researcher

1. Introduction

With the advancement of digital technology, CAD/CAM systems have enabled the fabrication of dental restorations. This approach is particularly well suited to zirconia, which can be processed in a soft, non-sintered state, and has therefore gained worldwide popularity. Compared with glass ceramics such as porcelain and castable ceramics, which have traditionally been the mainstream materials, zirconia exhibits superior strength and chemical stability, making it a more biocompatible material.

Dental zirconia has evolved rapidly over the past two decades since its introduction. Early zirconia exhibited high strength but low translucency and a white appearance; therefore, it was referred to as “white metal” and was primarily used as a framework material with porcelain layering as a substitute for metal. Subsequently, the development of highly translucent zirconia enabled its application in monolithic crowns and bridges in the posterior region. Further improvements in translucency have also made it possible to use zirconia for monolithic crowns and bridges in the anterior region.

At YAMAKIN, "KZR-CAD Zirconia" series has been developed as ceramics for dental machining. The product lineup includes the "NANOZR" and "T" series, which are technical zirconia products characterized by excellent mechanical strength and machinability, as well as the "SHT" and "HT" series, which are aesthetic zirconia products featuring enhanced translucency with a focus on aesthetics. Furthermore, in response to increasing demands for higher aesthetic performance, the company has commercialized "KZR-CAD Zirconia Gradation," a zirconia disc composed of multiple layered shades ranging from enamel to ivory, enabling reproduction of natural tooth coloration (Figure 1-1).

As dental zirconia has evolved, as described above, its translucency has increased, whereas its strength has decreased. This is because the mechanical strength and translucency of most dental zirconia materials are largely governed by the amount of yttria added for partial stabilization. In other words, a trade-off exists between strength and translucency: highly translucent zirconia exhibits favorable aesthetic properties but relatively low strength, whereas high-strength zirconia is suitable for long-span bridges but demonstrates low translucency and inferior aesthetics.

In dental restorations, it is ideal for the incisal edge of a crown to exhibit high translucency, while the central and cervical regions should possess higher opacity to minimize the influence of the abutment tooth color - particularly in the case of titanium abutments, which have a metallic appearance. For this reason, mixed-composition layered zirconia has been developed by combining zirconia materials with different translucencies and strengths. Specifically, zirconia with high translucency and lower strength is layered in the incisal region, while zirconia with lower translucency and higher strength is applied to the central and cervical regions. This design is highly rational for crowns and bridges.

However, because the highly translucent incisal layer is mechanically weaker than the cervical layer, the application of mixed-composition layered zirconia has been difficult in restorations such as inlays, which require uniform margins and simultaneously demand both high translucency and high strength. In other words, although translucency varies from the incisal to the cervical region, the ideal zirconia material would exhibit consistently high and stable strength throughout all layers.

In response to these technical challenges, YAMAKIN has developed and commercialized a newly designed* mixed-composition laminated (five layers) zirconia, "KZR-CAD Zr Laxio" (hereinafter referred to as "Laxio"). This material is fabricated using multiple zirconia powders with different characteristics, including the newly released zirconia powder "Zpex Smile.m[®]"¹⁾ supplied by Tosoh Corporation. Unlike conventional layered zirconia, Laxio is designed to maintain uniformly high mechanical strength across all layers from the incisal edge to the cervical region, while varying only the translucency.

In this chapter, the characteristics of the newly designed "Laxio" are presented and discussed in comparison with those of conventional single-composition zirconia products.

*In the KZR series

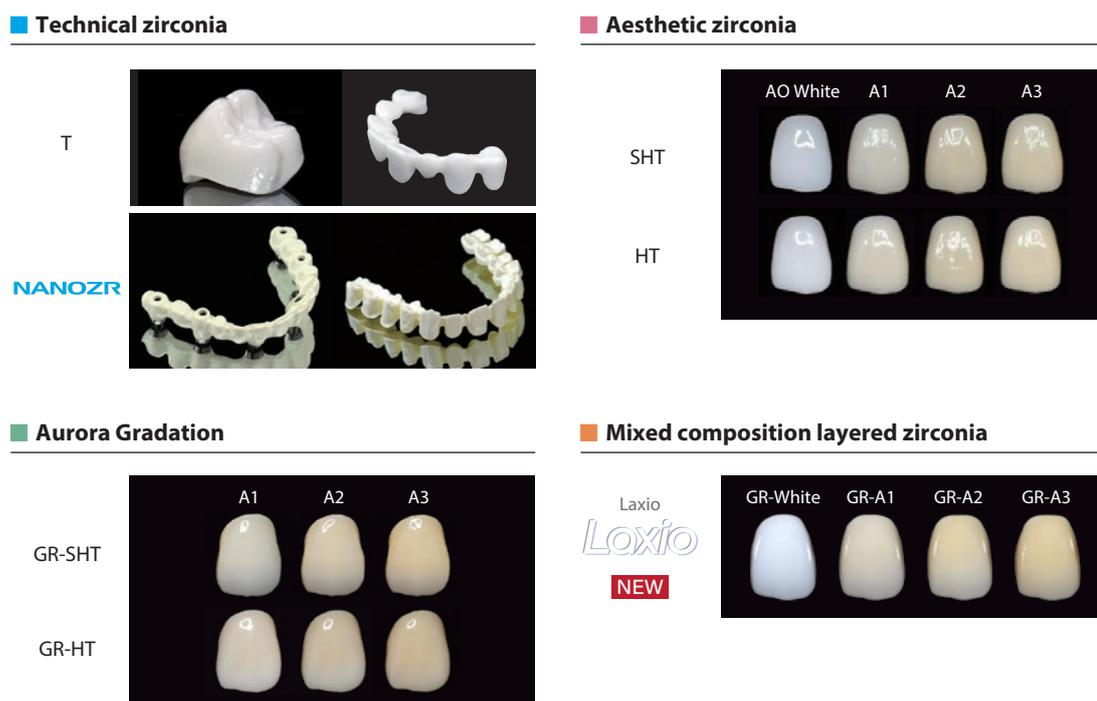


Figure 1-1 KZR-CAD Zirconia Series Lineup and New Product "Laxio"

2. Basics of Dental Zirconia

2.1. Crystal Structure and Strengthening of Zirconia

Pure zirconia exhibits three crystallographic phases - monoclinic, tetragonal, and cubic - and undergoes phase transformations depending on temperature (Figure 2-1). At room temperature, zirconia is stable in the monoclinic phase; with increasing temperature, it transforms sequentially to the tetragonal phase and then to the cubic phase.

These phase transformations are accompanied by changes in crystal volume. In particular, the transformation from the tetragonal to the monoclinic phase is associated with an approximate 4% volume expansion. The internal stresses generated by this volume increase can induce crack formation and propagation, ultimately leading to a reduction in mechanical strength.

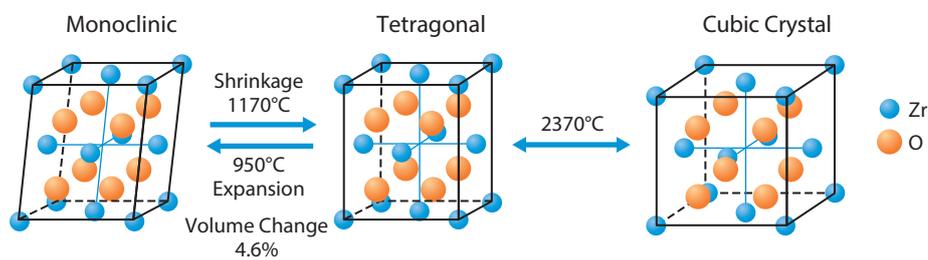


Figure 2-1 Schematic diagram of zirconia crystal structure change

Therefore, when stabilizers such as yttrium oxide (Y_2O_3), calcium oxide (CaO), or magnesium oxide (MgO) are added to zirconia to form a solid solution, the high-temperature cubic phase can be stabilized even at room temperature (Figure 2-2). Zirconia stabilized with Y_2O_3 is referred to as yttria-stabilized zirconia (YSZ).

When the amount of stabilizer added to zirconia is reduced, the resulting microstructure consists of a mixture of cubic and tetragonal phases, or a predominantly tetragonal phase. This state is known as partially stabilized zirconia (PSZ). In particular, when approximately 3 mol% Y_2O_3 is added, the tetragonal phase becomes nearly 100% stable at room temperature; this material is termed yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) and is widely used as a dental restorative material.

When stress is applied to Y-TZP, a stress-induced phase transformation from the tetragonal to the monoclinic phase occurs. This transformation is accompanied by an approximate 4% volume expansion, which generates compressive stress in the vicinity of a crack. This phenomenon, known as stress-induced phase transformation^{2,3}, produces compressive stress at the crack tip, thereby inhibiting crack propagation (Figure 2-3).

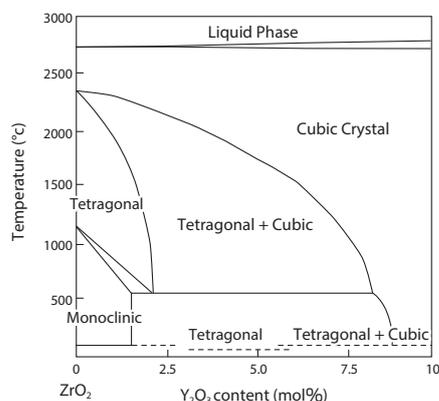


Figure 2-2 Phase diagram of ZrO_2 - Y_2O_3 system (modified from Reference 4)

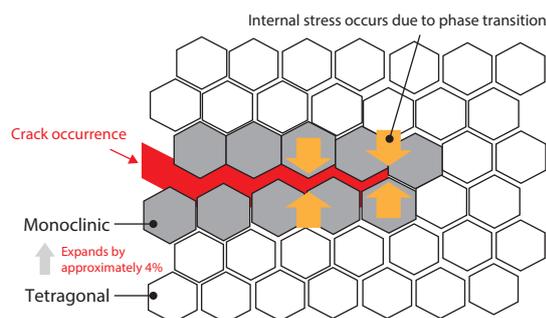


Figure 2-3 Schematic diagram of stress-induced phase transformation strengthening mechanism

2.2. Dental Zirconia Specifications

Dental ceramic materials are standardized under *JIS T 6526: 2018 Dental ceramic materials*, and *ISO 6872: 2015 Dentistry-Ceramic materials*, issued by the Japanese Industrial Standards and the International Organization for Standardization, respectively. As shown in Table 2-1, these standards classify dental ceramic materials into detailed categories according to their intended clinical applications, with differing requirements for flexural strength and allowable dissolution.

Table 2-1 Classification of ceramics for restorations and fixed prostheses by intended clinical use and required values of mechanical and chemical properties

Class	Recommended clinical indications	Mechanical and chemical properties	
		Flexural strength (MPa)	Chemical solubility ($\mu\text{g}\cdot\text{cm}^{-2}$)
1	a) Monolithic ceramic for single-unit anterior prostheses, veneers, inlays, or onlays adhesively cemented.	50 and over	Less than 100
	b) Ceramics for coverage of a metal framework or a ceramic substructure.		
2	a) Monolithic ceramic for single-unit anterior or posterior prostheses adhesively cemented.	Over 100	Less than 100
	b) Fully covered substructure ceramic for single-unit anterior or posterior prostheses adhesively cemented.	Over 100	Less than 2000
3	a) Monolithic ceramic for single-unit anterior or posterior prostheses and for three-unit prostheses not involving molar restoration adhesively or non-adhesively cemented.	Over 300	Less than 100
	b) Fully covered substructure for single-unit anterior or posterior prostheses and for three-unit prostheses not involving molar restoration adhesively or non-adhesively cemented.	Over 300	Less than 2000
4	a) Monolithic ceramic for three-unit prostheses involving molar restoration.	Over 500	Less than 100
	b) Partially or fully covered substructure for three-unit prostheses involving molar restoration.	Over 500	Less than 2000
5	Monolithic ceramic for prostheses involving partially or fully covered substructure for four or more units.	Over 800	Less than 100

Dental zirconia prostheses are generally applied to restorations involving four or more connected units; therefore, they are required to comply with the requirements of Class 5, which specifies the highest level of mechanical strength. At present, zirconia is the only dental ceramic material that satisfies this classification while providing sufficient strength for such applications.

In contrast, "SHT" zirconia, which exhibits excellent translucency but comparatively lower flexural strength, corresponds to Class 4a). This material is suitable for monolithic ceramic restorations involving up to three connected units, including applications in the molar region.

3. Features of "KZR-CAD Zr Laxio"

3.1. Material design

As shown in Figure 3-1, "Laxio" is designed using zirconia powders with 3Y, 4Y, and 5Y yttria contents, in combination with "Zpex Smile.m[®]," a newly released zirconia powder developed by Tosoh Corporation. "Zpex Smile.m[®]" is an advanced material that offers superior performance compared with the conventional "Zpex Smile[®]" and has been reported to exhibit the following advantages: (1) approximately 30% higher mechanical strength; (2) minimal reductions in strength and translucency, even under high-speed sintering conditions; and (3) a firing shrinkage rate comparable to that of other raw materials, resulting in reduced susceptibility to warping and cracking.

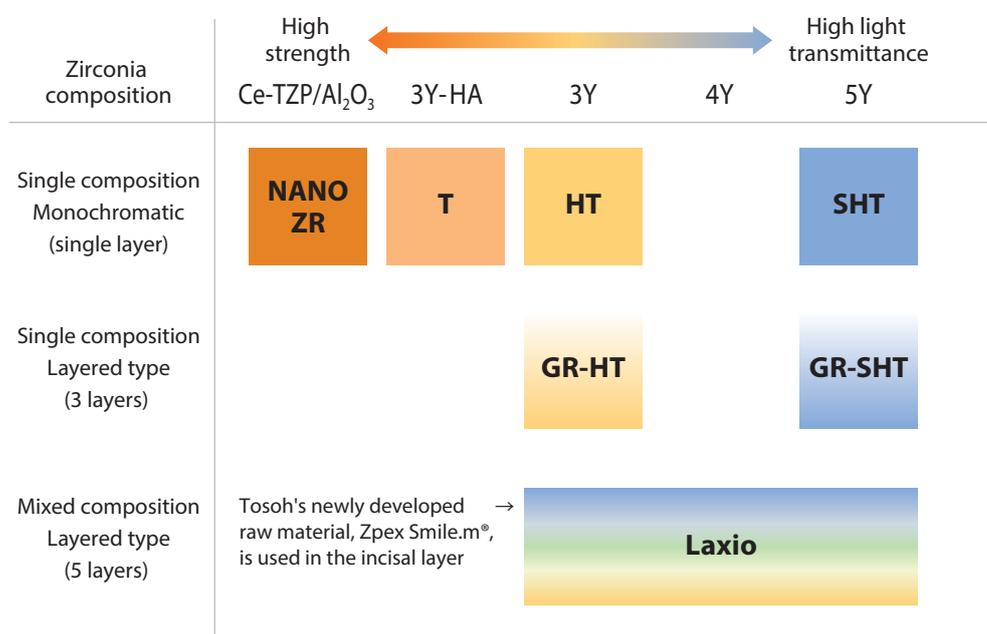
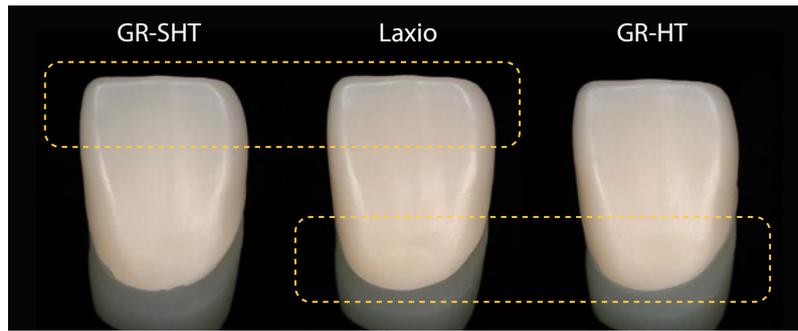


Figure 3-1 Zirconia composition by product

3.2. Aesthetics

"Laxio" is a mixed-composition layered zirconia material fabricated by combining and layering zirconia raw materials such that the incisal edge exhibits high translucency, while the central and cervical regions possess lower translucency and higher mechanical strength. In other words, as shown in Figure 3-2, the incisal region of "Laxio" demonstrates translucency comparable to that of "KZR-CAD Zirconia Gradation SHT" (hereinafter referred to as GR-SHT), whereas the cervical region exhibits low translucency and high mechanical strength equivalent to "KZR-CAD Zirconia Gradation HT" (hereinafter referred to as GR-HT).



*Photo shows A2 shade

Figure 3-2. Aesthetic properties and translucency of "Laxio"

3.3. Transmittance

To quantitatively evaluate the transmittance of "Laxio" (shade: GR-White), specimens were sectioned parallel to the disk surface from each layer corresponding to the incisal, central, and cervical regions and subsequently sintered at 1450 °C for 2 hours. After sintering, plate-shaped specimens with a diameter of 12 mm and a thickness of 1 mm were prepared by polishing both surfaces to a mirror finish. The total luminous transmittance [T_t] was then measured using a turbidity meter (NDH4000, Nippon Denshoku Industries Co., Ltd.), as schematically illustrated in Figure 3-3.

For comparison, identical measurements were performed for the conventional products "GR-SHT" and "GR-HT," and the corresponding T_t values are summarized in Table 3-1.

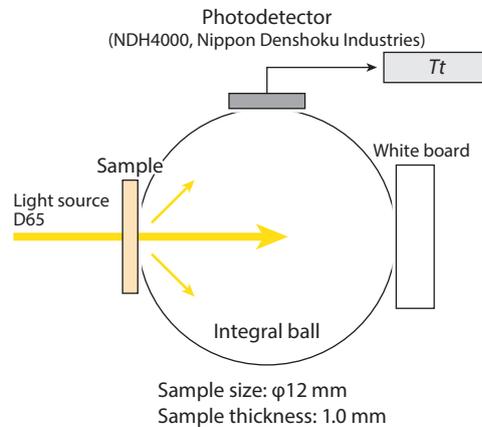


Figure 3-3 Schematic diagram of transmittance measurement method

The transmittance of the incisal region of "Laxio" (shade: GR-White) was intermediate between those of "GR-SHT" and "GR-HT," whereas the transmittance of the cervical region was approximately equivalent to that of "GR-HT."

Table 3-1 Transmittance of each layer

		GR-SHT	Laxio	GR-HT
Transmittance (%, 1 mm, white)	Incisal edge	51	46	43
	Central part	51	44	43
	Cervical region	51	42	43

3.4. Shielding

A key feature of this mixed-composition layered zirconia is the reduced translucency from the central to the cervical region, which minimizes the influence of the underlying abutment color, including metal and resin abutments. The photographs of monolithic crowns presented in Table 3-2 provide a comparative evaluation of the effects of abutment materials (core resin and titanium alloy) and resin cement shades (clear and opaque) on the appearance of "GR-SHT," "Laxio," and "GR-HT."

Table 3-2 Comparison of the effects of abutment material and resin cement shade on zirconia restorations

GR-SHT			
Laxio			
GR-HT			
Abutment tooth material	Core resin	Titanium alloy	Titanium alloy
Color of resin cement	Clear	Clear	Opaque color

To further investigate color characteristics, a spectrophotometer (PR-650; Photo Research Co., Ltd.) was used to measure the color of the incisal, central, and cervical regions of monolithic crowns cemented to each abutment. As schematically illustrated in Figure 3-4, the color differences between crowns placed on core resin abutments and those placed on titanium alloy abutments were calculated, and the results are summarized in Table 3-3.

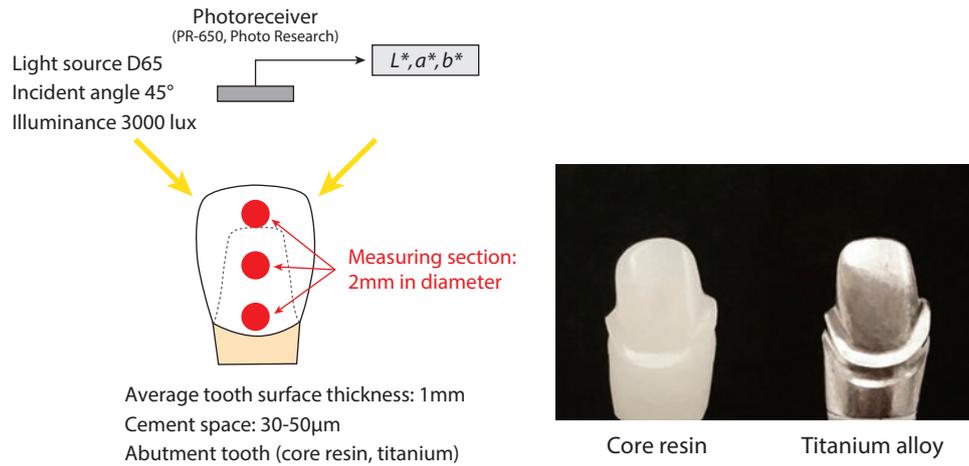


Figure 3-4 Schematic diagram of color measurement of a monolithic crown and appearance of the abutment tooth

As shown in the photographs in Table 3-2, the highly translucent "GR-SHT" exhibited the largest color difference ($\Delta E = 6.4 - 7.7$) among the evaluated materials when clear cement was used on titanium alloy abutments. In contrast, when opaque cement was applied, the color difference decreased to $\Delta E = 2.1 - 3.8$, reflecting the influence of the cement color.

"Laxio" exhibited an intermediate color difference ($\Delta E = 3.3 - 4.2$) when clear cement was used; however, the values decreased to $\Delta E = 0.9 - 1.4$ when opaque cement was applied, a range that is generally considered visually imperceptible. "GR-HT," which has low translucency, similarly exhibited small ΔE values comparable to those of "Laxio."

Table 3-3 Color differences of monolithic crowns for each product between core resin abutments cemented with clear resin cement and titanium alloy abutments cemented with clear and opaque resin cements

		GR-SHT		Laxio		GR-HT	
Color of resin cement		Clear	Opaque color	Clear	Opaque color	Clear	Opaque color
Color difference ΔE	Incisal edge	6.4	2.1	3.3	0.9	3.7	1.6
	Central part	7.7	3.5	3.8	1.4	3.9	1.5
	Cervical region	7.7	3.8	4.2	1.4	4.1	1.3

In addition, "GR-SHT" and "GR-HT" are designed with a three-layer structure, as each layer exhibits uniform translucency (aurora gradation). In contrast, "Laxio" employs a five-layer structure in which layers with different levels of translucency are sequentially stacked. This design suppresses edge contrast (Mach band artifacts) that can occur at the interfaces between layers, thereby enhancing the overall aesthetic appearance (Figure 3-5).

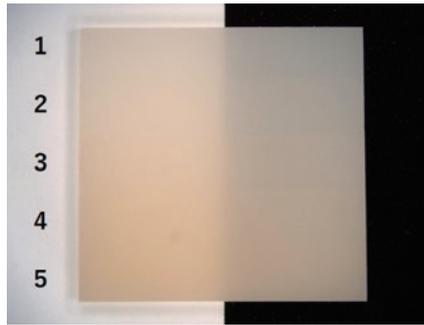


Figure 3-5 Cross-sectional appearance and changes in color tone and translucency of the "Laxio" laminate (thickness: 0.5 mm)

3.5. Strength

To evaluate the three-point flexural strength of each layer corresponding to the incisal, central, and cervical regions, "Laxio" (shade: GR-White) was examined. Specimens were sectioned from each layer and prepared, in accordance with *JIS T 6526: 2018 (Dental Ceramic Materials)*, to dimensions of 4.0 ± 0.2 mm in width, 1.2 ± 0.2 mm in thickness, with a 0.1 mm chamfer, and a length of 20 mm after sintering. The flexural strength of the specimens was then measured using a precision universal testing machine (AG-X; Shimadzu Corporation).

For comparison, specimens of "GR-SHT" and "GR-HT" were prepared and tested under identical conditions.

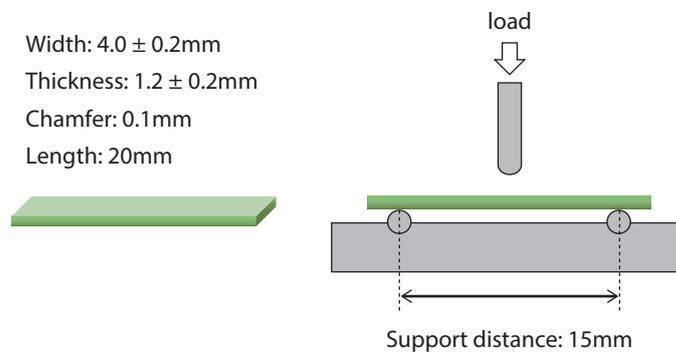


Figure 3-6 Schematic diagram of three-point flexural test method

The results of the three-point flexural strength test are presented in Figure 3-7 and Table 3-4. "Laxio" exhibited high flexural strength values exceeding 1100 MPa in the incisal, central, and cervical regions. In contrast, "GR-SHT" demonstrated a flexural strength of approximately 770 MPa across all layers; therefore, it is classified as Class 4 according to *JIS T 6526: 2018 (Classification and Use of Dental Ceramic Materials)*, limiting its application to restorations involving up to three connected units.

"Laxio" meets the requirements for Class 5 (≥ 800 MPa) under the same classification, comparable to "GR-HT," which exhibits flexural strength values of approximately 1200 MPa in each layer. These results confirm that "Laxio" can be widely applied as both monolithic and framework ceramics for connected prostheses involving four or more units.

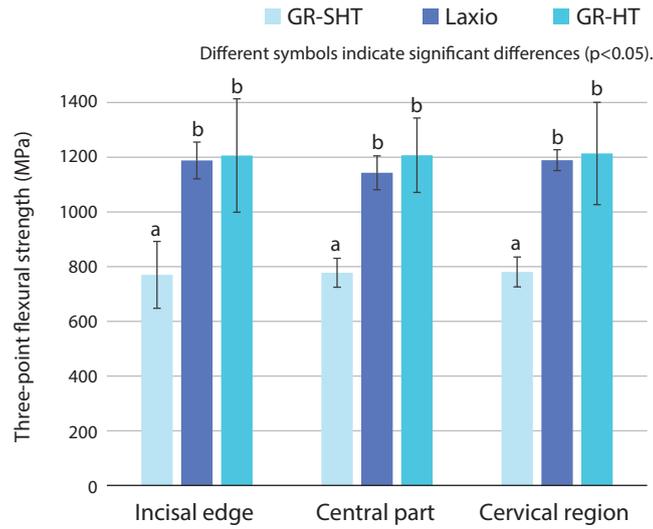


Figure 3-7 Three-point flexural strength of each product in the incisal, central, and cervical layers

Table 3-4 Three-point flexural strength of each product in the incisal, central, and cervical layers

		GR-SHT	Laxio	GR-HT
Three-point flexural strength (S.D.) [MPa]	Incisal edge	770 (122)	1188 (67)	1206 (207)
	Central part	778 (53)	1143 (62)	1207 (136)
	Cervical region	781 (55)	1189 (38)	1214 (187)

3.6. Chipping Resistance

During cutting and final adjustment of dental zirconia restorations, chipping is likely to occur at thin marginal areas of the crown, which may subsequently lead to fractures after intraoral placement. Although "GR-SHT" offers high translucency and excellent aesthetics, chipping during marginal adjustment has been a notable concern.

As shown in Figure 3-8, "Laxio" is designed to maintain high mechanical strength and good machinability from the incisal edge to the cervical region. This material design enables safer and more reliable marginal adjustment, thereby improving resistance to chipping during clinical procedures.

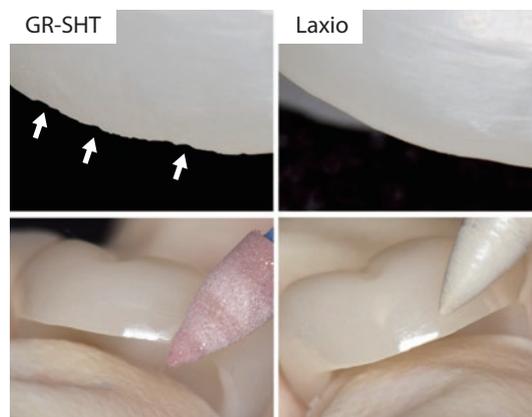


Figure 3-8 Polishing and machining properties of "Laxio" (chipping resistance)

3.7. Summary of Laxio Features

As summarized in Table 3-5, "Laxio" exhibits uniformly high three-point flexural strength exceeding 1100 MPa across all layers, while its transmittance varies depending on the layer. This unique combination provides material characteristics that are not achievable with conventional dental zirconia, in which translucency and strength are generally regarded as being in a trade-off relationship.

These properties allow "Laxio" to be safely used regardless of the cutting position of the prosthesis, enabling flexible material selection based on the translucency and morphology required for each clinical case, as illustrated in Figure 3-9. Consequently, beyond its application in crowns and bridges – where mixed-composition laminated zirconia has traditionally been used to provide low translucency and high strength at thin marginal areas - "Laxio" is also well suited for inlays, onlays, laminate veneers, and other restorations that require both high translucency and high strength with circumferential margins. Therefore, a wide range of clinical applications is anticipated.

Table 3-5 Three-point flexural strength and transmittance of the incisal, central, and cervical layers of "Laxio" (shade: GR-White)

	Three-point flexural strength (S.D.) [MPa]	Transmittance (% , 1 mm, white)
Incisal edge	1188 (67)	46
Central part	1143 (62)	44
Cervical region	1189 (38)	42

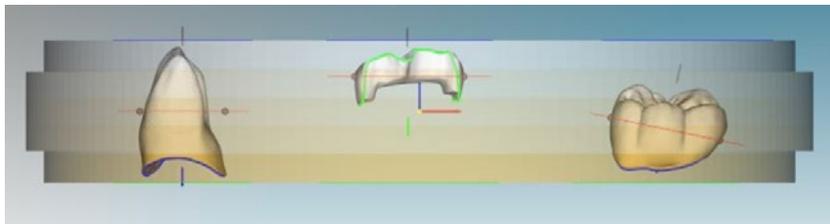


Figure 3-9 Translucency at different cutting positions of the prosthesis

4. Conclusion

Zirconia for dental machining was approved as a medical device in Japan in 2005. At that time, it was available only in white and was therefore referred to as "white metal." In recent years, driven by rapid advancements of dental CAD/CAM systems, the translucency of zirconia has markedly improved, and a wide variety of shaded materials has been developed. Many contemporary products now provide not only sufficient strength and durability for use in anterior restorations without porcelain veneering, but also enhanced aesthetic performance.

More recently, multi-gradation zirconia materials with mixed-composition laminated structures, in which strength and translucency vary among layers, have attracted considerable attention. In contrast, "Laxio" is a zirconia material characterized by uniformly high mechanical strength across all layers, thereby overcoming the conventional paradigm of dental zirconia in which translucency and strength are considered to be in a trade-off relationship.

Owing to this unique property, "Laxio" is suitable for inlays, onlays, laminate veneers, and other restorations that require both high translucency and high strength, as well as thin circumferential margins. This material is therefore expected to be applicable to a wide range of clinical applications.

Literature

- 1) TOSOH ZIRCONIA POWDER Technical bulletin, Technical Data Sheet Zpex Smile.m[®].
- 2) T. K. Gupta, F. F. Lange, J. H. Bechtold, Effect of stress-induced phase transformation on the properties of polycrystalline zirconia containing metastable tetragonal phase, *J. Mater. Sci.*, 13, 1464-1470, 1978.
- 3) M. V. Swain, L. R. F. Rose, Strength limitations of transformation-toughened zirconia alloys, *J. Am. Ceram. Soc.*, 69, 511-518, 1986.
- 4) H.G.Scott, *J. Mater. Soc.*, 10, 1527-35, 1975.

Product lineup

CAD/CAM Zirconia Disc



KZR-CAD Zr Laxio

KZR-CAD Zr Laxio

Controlled Medical Device: Zirconia Blank for Dental Milling and Machining
Certification Number: 304AFBZX00051000



KZR-CAD NANOZR

KZR-CAD NANOZR

Controlled Medical Device: Zirconia Blank for Dental Milling and Machining
Certification Number: 229AABZX00032000

Related products

Stain porcelain for zirconia



ZEO CE LIGHT ZR

ZEO CE LIGHT ZR

Controlled Medical Device: Ceramics Material
Certification Number: 227AFBZX00042000

Diamond-containing abrasives



C&B DIAMOND POLISHER

C&B Diamond Abrasives

Notification Number: 39B2X10002000001



C&B NANO DIAMOND POLISHER

C&B Nano Diamond Abrasive

Notification Number: 39B2X10002000002

The colors of products, models, packaging, etc. may appear different from the actual colors due to printing inks, photography conditions, etc. The data listed may vary depending on conditions. Product specifications, appearance, containers, etc. may change without notice. Please be sure to check the latest electronic appendix when using the product.

Manufacturer **YAMAKIN CO., LTD.** Head Office: 1090-3 Kamibun, Kagami-cho, Konan-shi, Kochi, 781-5451, Japan

Editor: Takahiro Kato
Publisher: Shigenari Yamamoto
Publication Date: February 13, 2023, 1st Edition
Publication Date: June 9, 2024, 2nd Edition



YAMAKIN CO., LTD.

Head Office: 1090-3 Kamibun, Kagami-cho, Konan-shi, Kochi, 781-5451, Japan
Biological Science Safety Laboratory:
Laboratory in the Department of Oral and Maxillofacial Surgery, Kochi Medical School, Kochi University
Kohasu, Oko-cho, Nankoku-shi, Kochi 783-8505, JAPAN
Branch Office: Osaka, Tokyo, Nagoya, Fukuoka, Sendai, JAPAN
P: +81-88-888-0290
E: contact@yamakin-gold.co.jp
<https://www.yamakin-global.com>