Evaluation of Machinability and Properties of Novel Glass－Ceramic Materials for Dental All-Ceramic Crowns

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ABSTRACT

Dental ceramic applied to oral technology has been two hundred years of history. All-ceramic crowns in the production technology and components also increasingly progress. A glass-ceramic crown as the main ingredients in commercial products occupy an important position. The reason is that glass-ceramic glass can be controlled through the crystallization of the extent of the production of polycrystalline. Also can change the composition and the elements required of glass by the nature of glass-ceramic. Calcium-mica is known as one of fluorophlogopite type mica. The feature of the calcium-mica are the great glass stability of the melt and machinability. The experimental use of calcium mica and glass system which by Wu et al. research and development components for the proportion of mixed glass-ceramic. Expect to be able to produce a machinability of all-ceramic crowns. Experimental steps include differential thermal analysis, XRD crystalline phase analysis, SEM analysis of micro-structure and mechanical properties. The results are calcium-mica and apatite generated at 882℃ at the same time, but the crystallization of calcium-mica is more obvious. Sintering temperature is higher, calcium-mica and apatite crystal are higher. Added calcium-mica ratio reached 70%, glass-ceramic will be natural fragmentation in the air.The mechanical tests include micro-hardness test and machinability test. In micro-hardness experimental results, added calcium-mica in glass, will increase the glass-ceramic hardness after sintering. The machinability test assessment using cutting speed and cutting edge integrity to comprehensive assess. All of the specimens compared with commercial dental materials IPS e.max CAD and cercon base 12. The best machinability specimen is 50G50C of 950℃ for the heat treatment.

Keywords : All-ceramic crown ; Calcium-mica ; Machinability

Table of Contents

REFERENCES

[1] Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: historical roots and current perspectives. J Prosthet Dent 1996;75(1):18-32.
[2] Rosenblum M, Schulman A. A review of all-ceramics restorations. J Am Dent Assoc 1997;128(3):297-307.
[3] Ironside JG, Swain MV. Ceramic in dental restorations-a review and critical issues. J Aust Ceram Soc 1998;34(2):78-91.
[4] Doremus RH. Review bioceramics. J Mater Sci 1992;27:285-297.
[5] Hansen S. Preparations for Cerec 3: where are the limits. Int J Comput Dent 2000;3:197-205.
[6] Kelly JR. Ceramics in restorative and prosthetic dentistry. Mater Sci 1997;27:443-468.
[7] Anusavice KJ. Recent developments in restorative dental ceramics. J Am Dent Assoc 1993;124:72-84.
[8] Simonsen RJ. Materials horizon. J Am Dent Assoc 1991;122:25-31.
[9] Cales B. Colored zirconia ceramics for dental applications. Bioceramics 1998;11:591-594.
[10] Giordano RA. Dental ceramic restorative systems. Compend Contin Educ Dent 1996;17(8):779-794.
[11] Doremus RH. Review Bioceramics. Mater Sci 1992;27:285-297.
[12] Christensen GJ. Why all-ceramic crowns. J Am Dent Assoc 1997;128:1453-1455.
[13] Brenner MDK. The story of dentistry. London: Kimpton publishers, 1959.p. 107.
[14] 林琮欽, 陳柏志, 陳志源, 葉竹原, 鍾明哲. 最新固定假牙贋復學. 合記圖書出版社. 2005. p. 643-644.
[15] Weinstein M, Weinstein AB: Fused porcelain-to-metal teeth. U.S. Patent No. 3,052,982. Sept 11, 1962.
[16] Derek WJ. Development of dental ceramics: An historical perspective. Dent Clini North Am 1985;29 (4), p. 621-645.
[17] Combe EC, Trevor Burke FJ, Douglas WH. Dental biomaterials, Boston:Kluwer Academic Publishers, 1999.p. 476.
[18] Williams DF. Biocomatibility of Clinical implant materials. v2. CRC press Inc Boca Raton. Florida, 1981. p. 112.
[19] 鐘國雄. 牙科材料學. 合記圖書出版社. 1994.p. 191.
[20] Tyszblat M. Process of preparation of a dental prosthesis by slight solid phase fritting of a metal oxide based infrastructure. US Patent No. 4772436, 1987.
[21] Seghi RR. Flexural strength of new ceramic materials. J Dent Res 1990;69:299.
[22] Wolf WD. Mechanical properties and failure analysis of alumina-glass dental composites. J Amer Ceram Soc 1996;79:1769.
[23] McLaren EA. All-ceramic alternatives to conventional metal-ceramic restorations. Compend Contin Educ Dent 1998;19:307.
[24] Sorensen JA. Core ceramic flexural strength from water storage and reduced thickness. J Dent Res 1999;78:219.
[25] Shearer B. Influence of marginal configuration and porcelain addition on the fit of In-Ceram crowns. Biomaterials 1996;17:1891.
[26] Pera P. In vitro marginal adaptation of alumina porcelain ceramic crowns. J Prosthet Dent 1994;72:585.
[27] Sulaiman F. A comparison of the marginal fit of In-Ceram, IPS Empress, and Procera crowns. Int J Prosthodont 1997;10:478.
[28] Wang MC, Wu NC, Hon MH. Preparation of nepheline glass-ceramics and their application as dental porcelain. Mater Chem Phys 1994;37:370-375.
[29] Radovan D, Vera D, Predrag V, Smilja M, Slobodan M. Structural characterization of pure Na-nephelines synthesized by zeolite conversion route. J Phys Chem Solids 2004;65:1623-1633.
[30] Hamzawy Esmat MA, El-Meliegy Emad M. Crystallization in the Na2O-CaO-Al2O3-SiO2-(Lif) glass compositions. Ceram Int 2007;33:227-231.
[31] Slopen JV, Hobatha MC, Verdonck P. Applications of computer modeling for the design of orthopaedic, dental and cardi ovascular biomaterials. J Eng Med 1998;212 (H6):489-500.
[32] Rosenblum MA, Schulman A. A review of all-ceramic restorations. J Am Dent Assoc. 1997;128(3), 297-307.
[33] Bayne SC, Heymann HO. CAD/CAM in dentistry:Present and future applications. Quintessence. Int 1996;27(6), 431-437.
[34] Zhang WY, Gao H, Li BY, Jiao QB. A novel route for fabrication of machinable fluoramphibole glass-ceramics, Scr Mater 2006;55, 275-278.
[35] Beall GH. in: L.L. Hench, Freiman, Editors. Advances in nucleation and crystallization in glasses. American Ceramic Society, Westerville, OH, 1971. p. 251.
[36] Chyung CK, Beall GH, Grossman DG. in: Electron microscopy and structure of materials, Proceedings of 5th international materials symposium, University of California, Berkeley, CA, 1971. p. 1167.
[37] Grossman DG. Machining a machinable glass-ceramic. Am Mach 1978;122.
[38] Beall GH. Design and Properties of Glass-Ceramics, Annual Review of Materials Science. 1992;22(8):91-119.
[39] Habelitz S, Hoeche T, Hergt R, Carl G, Russel C. Microstructural design through epitaxial growth in extruded mica glass-ceramics. Acta Materialia 1999;(47) 2831.
[40] Uno T, Kasuga T, Nakyama S, Ikushima AJ. Microstructure of Mica-Based Nanocomposite Glass-Ceramics. J Am Ceram Soc, 1993;(76) 539-541.

[41] Comeforo JE, Hatch RA, Humphrey RA, Eitel W. Synthetic mica investigation: I A hot-pressed machinable ceramic dielectric. J Am Ceram Soc 1953;36(9): 286-294.
[42] El-Meliegy Emad M. Machinable spodumene-fluorophlogopite glass ceramic. Ceram Int 2004;30:1059-1065.
[43] Uno T, Kasuga T, Nakayama S. Preparation of high-strength calcium-mica-containing machinable glass-ceramics. J Ceram Soc 1992;100(5):703-707.
[44] Meulen J, Koerten HK. Inflammatory response and degradation of three types of calcium phosphate ceramic in a non-osseous environment. J Biomed Mater Res 1994;28(12):455-463.
[45] Hoeland W, Naumann K, Vogel W. Machinable bioactive glass ceramics material. DE 3306648A, 1983.
[46] Strnad Z. in: Glass Science and Technology 8: Glass-Ceramic Materials. Elsevier, Amsterdam, 1986. p.107.
[47] Chyung GK, Beall GH, Grossman DG. in: Proceedings of 19th International Congress on Glass. Kyoto, Japan, 1974. p. 33.
[48] Holand W, Vogel W, Naumann K, Gummel J. Interface reactions between machinable bioactive glass-ceramics and bone. J Biomed Mater Res, 1985;19:303-312.
[49] Vogel W. Perspective of the development of bioactive glass ceramics for biomedical applications. J Non-Cryst Solids, 1985;73:593.
[50] Vogel W, Holand W, Naumann K, Gummel J. Development of machineable bioactive glass-ceramics for medical uses, J Non-Cryst Solids, 1986;80:34.
[51] Vogel W, Holand W. The development of bioglass ceramics for medical applications. Angew Chem Int Ed Engl, 1987;26:527.
[52] Holand W, Wange P, Naumann K, Vogel J, Carl G, Jana C, Gotz W. J Non-Cryst Solids, 1991;129:152.
[53] Holand W, Vogel W, Naumann K, Carl G, Wange P, Vogel J, Gotz W. in: P. Vincenzini editors, Ceramics in Substitutive and Reconstructive Surgery, Elsevier, Amsterdam, 1991. p. 121.
[54] Holand W, Vogel W. in: Hench LL, J. Wilson Editors. An Introduction to Bioceramics, Advanced Series in Ceramics, vol. 1, World Scientific, Singapore, 1993. p. 125.
[55] Zhang X, Chen X, Li B. Effect of Heat-Treatment and Addition on the Crystallization Features of Bioactive Glass Ceramics. J Trace Microprobe Tech 1997; 15.p. 713.
[56] Chen X, Hench LL, Greenspan D, Zhong J, Zhang X. Investigation on phase separation, nucleation and crystallization in bioactive glass-ceramics containing fluorophlogopite and fluorapatite. Ceram Int 1998;24:401-410.
[57] Honda SN, Beall GH. in: Simmons JH, Uhlmann DR, Beall GH. editors, Advances in Nucleation and Crystallization in Glasses, American Ceramic Society, Westerville, OH, 1982. p. 287.
[58] Taruta S, Mukoyama K, Suzuki SS, Kitajima K, Takusagawa N. Crystallization process and some properties of calcium mica-apatite glass-ceramics. J Non-Cryst Solids 2001;296:201-211.
[59] Taruta S, Sakata M, Yamaguchi T, Kitajima K. Crystallization process and some properties of novel transparent machinable calcium-mica glass-ceramics, Ceram Int 2008;34:75-79.
[60] 吳世經. 鈣磷生醫玻璃之結晶及其性質研究. 國立成功大學材料科學及工程研究所博士論文. 1995.
[61] 張柳春, 郭行健. 材料科學與工程. 學銘圖書有限公司,歐亞書局有限公司. 2005.p. 464-465.
[62] R.C. Mackenzie. Nomenclature in thermal analysis, part IV. Thermochim Acta 1979;28:1.
[63] R. C. Mackenzie. The origin of thermal analysis. Isr J Chem 1982;22:203-205.
[64] 陳道達. 熱分析. 渤海堂文化事業有限公司. 1992.p. 251.
[65] 柯以侃, 吳明珠. 儀器分析. 文京圖書有限公司. 1996.p. 564-585.
[66] 邱念華. 儀器分析實驗. 新文京開發出版股份有限公司. 2003.p. 301-305.
[67] 王明光, 王敏昭. 實用儀器分析. 合記出版社. 2003. p. 222-236.
[68] Hench LL, Splinter RJ, Allen WC. Bonding mechanisms at the interface of ceramic prosthetic materials. J Biomed Mater Res Symp 1971;2:117-141.
[69] Liu Y, Sheng X, Dan X, Xiang Q. Preparation of mica/apatite glass-ceramics biomaterials. Mater Sci and Eng C 2006;26:1390-1394.
[70] T Kokubo, S Ito, S Sakka. Formation of a high-strength bioactive glass-ceramics in the system MgO-CaO-SiO2-P2O5. Mater Sci 1986;21(2):536-540.
[71] Beall GH. Advances in Nucleation and Crystallization in Glasses. Columbus. USA: The American Ceramic Society, 1971.
[72] Crossman DG. Machinable glass-ceramics based on tetrasilicic mica. J Am Ceram Soc 1972;55:446-449.
[73] Chen XF, Hench LL, Greenspan D, J Zhong, Zhang X. Investigation on phase separation, nucleation and crystallization in bioactive glass-ceramics containing fluorophlogopite and fluorapatite. Ceram Int 1998;24(5):401-410.
[74] Taruta S, Watanabe K, Kitajima K, Takusagawa N. Effect of titania addition on crystallization process and some properties of calcium mica-apatite glass-ceramics. J Non-Cryst Solids 2003;321:96-102.
[75] Noda T. Synthetic mica research in Japan. J Am Ceram Soc 1955;38(4):147-152.
[76] Mustafa Emad A A. Fluorophlogopite porcelain based on talc-feldspar mixture. Ceram Int 2001;27:9-14.
[77] Marghussian VK, Mesgar A, Sheikh-Mehdi. Effects of composition on crystallization behaviour and mechanical properties of bioactive

glass-ceramics in the MgO-CaO-SiO2-P2O5 system. Ceram Int 2000;26:415-420.
[78] Laczka M, Cholewa-Kowalska K, Laczka-Osyczka A, Tworzydlo M, Turyna B. Gel-derived materials of a CaO-P2O5-SiO2 system modified by boron, sodium, magnesium, aluminum, and fluorine compounds. J Biomed Mater Res 2000;52:601-612.
[79] Laczka M, Cholewa K, Laczka-Osyczka A. Gel-derived powders of CaO-P2O5-SiO2 system as a starting material to production of bioactive ceramics. J Alloys Compd 1997;248:42-51.
[80] Yu B, Liang K, Gu S. Effect of the microstructure on the mechanical properties of CaO-P2O5-SiO2-MgO-F- glass ceramics. Ceram Int 2003;29:695-698.
[81] Dalal KH, Davis RF. Beta spodumene-mica glass-ceramics I, phase evolution and microstructure. Ceram Bull 1977;26:991-997.
[82] Radonjic L, Nikolic L. The effect of fluorine source and concentration on the crystallization of machinable glass-ceramics. J Eur Cer Soc 1991;7:11-16.
[83] Hoche T, Habelitz S, II Knodos. Origin of unusual fluorphlogopite morphology in mica glass-ceramics of the system SiO2-Al2O3-MgO-K2O-Na2O-F2. J Crystal Growth 1998;192:185-195.
[84] Cheng K, Wan J, Liang K. Differential thermal analysis on the crystallization kinetics of K2O-B2O3-MgO-Al2O3-SiO2-TiO2-F glass. J Am Ceram Soc 1999;82:1212-1216.
[85] Carl G. Crystallization behaviour and properties of a mica glass-ceramic with various additions of TiO2 and ZrO2. In: Proceedings of the XVII international congress on glass. v5. Beijing, China, 1995. p. 343-348.
[86] Eftekhari Yekta B, Hashemi Nia S, Alizadeh P. The effect of B2O3, PbO and P2O5 on the sintering and machinability of fluormica glass-ceramics. J Eur Cer Soc 2005;25:899-902.
[87] Goeuriot D, Dubois JC, Merle D, Thevenot F, Exbrayat P. Enstatite based ceramics for machinable prosthesis applications. J Eur Ceram Soc 1998;18:2045-2056.
[88] Xu HHK, Kelley RJ, Jahanmir S, Thompson V, Rekow ED. Enamel subsurface damage due to tooth preparation with diamonds. J Dent Res 1997;76(1):1698-1706.
[89] Holand W, Schweiger M, Frank M, Rheinberger V. A comparison of the microstructure and properties of the IPS Empress 2 and the IPS Empress glass-ceramics. J Biomed Mater Res (Appl Biomater) 2000;53(4):297-303.
[90] Quinn J, Su L, Flanders L, Lloyd I. Edge toughness and material properties related to the machining of dental ceramics. Mach Sci Technol 2000;4:291-304.
[91] Albakry M, Guazzato M, Swain MV. Fracture toughness and hardness evaluation of three pressable all-ceramic dental materials. J Dentistry 2003;31(3):181-188.
[92] Yin L, Song XF, Song YL, Huang T, Li J. An overview of in vitro abrasive finishing & CAD/CAM of bioceramics in restorative dentistry. International Journal of Machine Tools & Manufacture 2006;46:1013-1026.
[93] Boccaccini AR. Machinability and brittleness of glass-ceramics. J Mater Proc Technol 1997;65:302-304.
[94] Taruta S, Ichinose T, Yamaguchi T, Kitajima K. Preparation of transparent lithium-mica glass-ceramics. J Non-Cryst Solids 2006;352:5556-5563.