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Flexural Behavior of Composite Material used for CAD/CAM

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[INTRODUCTION]

The flexural resistance is a fundamental propriety of prosthodontic materials and restorative materials. Another fundamental propriety of the flexural resistance and the influence on prosthetic material was discovered at the time of milling of CAD/CAM preforms. Indeed, there exists a direct relation between the size of the sectional area of a specimen, the preform support during milling and the arrow observed during the pressure of the work tool. This arrow, if it exists, is analyzed as a leeway in the precision, which is accentuated. Therefore, the flexural resistance has a direct relation with the precision. As a result, it is essential to know the value of flexural resistance or flexural deflection of a CAD/CAM preform in relation to it's sectional area and for a force applied to a point with an identical value at the average position of the milling tool. Recently, a composite material for CAD/CAM has been newly introduced. This material may have different deflection behavior from the other materials for CAD/CAM. The purpose of the present study is to investigate the deflection of the newly introduced composite material for CAD/CAM.

[MATERIALS AND METHODS]

Rectangular specimens with four different sizes (3×3×20mm, 5×5×20mm, 8×8×20mm, and 13×13×20mm) were prepared from a newly introduced composite for CAD/CAM (GC Corp, Tokyo, Japan). Each group consists of five light coloured preforms (A2) and five dark coloured preforms (B3). The three point flexural test at a support distance of 15 mm. Using a universal testing machine (Autograph DSS-5000, Shimadzu Ltd, Japan) with an extensometer, the specimen was subjected to flexural force at the cross-head speed of 1mm/min, and the force and deflection were recorded on a chart. From the chart, the deflection under 500gf was obtained. The data were analyzed using two-way ANOVA and a multiple comparison test.

[RESULTS AND DISCUSSION]

No significant difference in the deflection under 500gf was observed between different shades. On the other hand, the size significantly influenced on the deflection, with higher deflection at smaller size, mainly 3×3mm specimen as shows in fig.1, which may be related to the precision of the restoration using CAD/CAM.

Deformation of the support due to higher pressure exists but is constant with a slight deflection. During milling it is necessary never to exceed a certain tool cutting pressure on the preform if we want to obtain the precise surface of the CAD modelisation.

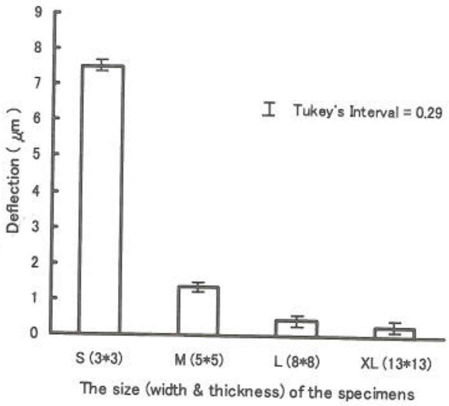

Fig1. The deflection of the different surface sections of the CAD/CAM composite specimen.

CAD CAM

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コンピュータ支援による補綴物の自動製作に関する研究（第１２報）切削加工におけるセラミック材料の検討

○小林幸隆，小澤　篤，李　元植，堀田康弘，藤原稔久，宮崎　隆　昭大・歯・理工

Automatic fabrication of prosthesis using a CAD/CAM process. (PART XII) Consideration of ceramic with machining

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［緒言］

現在、補綴物の審美的要求を満たすために用いられているセラミックスは、その製作手順の複雑さから歯科治療においても特別なものとして位置付けられている。しかし、近年コンピュータを用いた歯科用CAD/CAMシステムの開発により、こうした審美的な補綴物の製作を容易にする方法が多く発表されるようになってきた。当教室でも歯科用CAD/CAMシステムを開発し、セラミッククラウンの自動製作について研究、発表してきた。しかしながら、従来の金属や陶材の製作方法とは異なり、CAD/CAMシステムでは、材料のブロックを切削加工することで、目的とする補綴物の形状を作り出している。このため、CAD/CAMシステムに用いられるセラミックブロックは色調や質感についてよりも切削性を第一に考えられており、完成した補綴物の色調、質感はCAD/CAMで加工終了後の着色によるものが大であるが、加工前のセラミックブロックがより色調や質感に考慮されたものを加工に用いたほうが、より容易に審美的な補綴物が得られるはずである。そこで、現在、当教室で開発されているCAD/CAMシステムにおいて、どの程度まで審美的に考慮されたセラミックブロックを加工しうるか、また、加工されたセラミックブロックがどのような機械的性質を有するか検討を行った。

［材料および方法］

実験に用いたセラミックスは、オリンパス光学工業製のOCCを15×15×25mmの寸法のブロック状にし、焼成温度を880,900,920,940℃で行った4種類を使用した。なお、940℃のセラミックブロックがCAD/CAMシステムで現在使用中のものである。

実験－１　各セラミックブロックを精密低速切断器(アイソメット,BUEHLER)にて約1mmの厚さに切断し、片面を耐水研磨紙にて#1000まで表面を研磨、アセトンにて洗浄後、微小硬度計(MVK-E,明石)を用い体面角136°のビッカース圧子にて荷重9.8N、荷重保持時間20秒間にて圧痕を印記した。印記された圧痕より圧痕長を測定した。各試料につき5回計測を行い、ビッカース硬度(Hv)を求めた。

実験－２　各セラミックブロックを3×11×20mmの寸法の試験片を作製するNCデータに従い、加工速度以外の製作条件をCAD/CADMシステムの粗加工と同じである1回の切込み量を500μm、加工ピッチを500μmとし、加工速度を毎分100mmとして、直径3mmのボールエンドミル(チョウコウボールEM,日立ツール)を用いてCAD/CAMシステムを用いて切削加工を行った。得られた試験片を電子顕微鏡にて観察した。

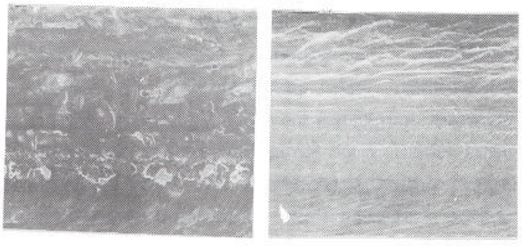
実験－３　3×4×18mmの寸法に切削加工するNCデータを用いて、CAD/CAMシステムを用いて各セラミックブロックを実験－２と同じ加工条件で直径3mmのボールエンドミルを用い切削加工を行い、加工後の試料は#1200の耐水研磨紙を用いて研磨を行い、加工時に加工ツールによって生じた鋭利な凹凸を除去し、試験片とした。また、各セラミックブロックとも5個づつ試験片を製作した。製作した試験片表面の状態を観察するために、表面性状測定器(SUPRFCOM480A,東京精密)を用い、各試料に対して5回、長軸方向に対し測定を行った。次いでインストロン万能試験機を用いて、JIS規格(R1601)に準じて、支点間距離16mm、クロスヘッドスピード0.5mm/minで三点曲げ試験を行い、破壊までの最大荷重から曲げ強さを求めた。

［結果及び考察］

表-1に各セラミックブロックのビッカース硬度を示す。940℃のブロックと他の3者との間でt検定で有意差が認められたが、他の3者間では認められなかった。また、色調、質感は880℃のブロックがもっとも優れていた。図-1に加工後の880℃と940℃のセラミックブロック表面のSEM像を示す。880℃のセラミックブロックでは940℃では認められない微小な亀裂が多数認められた。これらのセラミックの加工で、より良好な表面性状を得るためには、加工ツール及び、冷却液などを検討する必要があると思われる。

焼成温度	880℃	900℃	920℃	940℃
Hv(SD)	353(5.8)	362(10.0)	365(11.3)	287(13.3)

表-1　セラミックブロックのビッカース硬度



図－１　加工後のセラミック表面SEM像(×100)
880℃(左),940℃(右)

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INTRODUCTION

The flexural resistance is a fundamental propriety of prosthodontic materials and restorative materials. Another fundamental propriety of the flexural resistance and the influence on prosthetic material was discovered at the time of milling CAD/CAM preforms. Indeed, there exists a direct relation between the size of the sectional area of a specimen, the preform support during milling and the arrow observed during the pressure of the work tool. This arrow, if it exists, is analysed as a leeway in the precision, which is accentuated.

Therefore, the flexural resistance has a direct relation with the precision. As a result, it is essential to know the value of flexural resistance or flexural deflection of a CAD/CAM preform in relation to it's sectional area and for a force applied to a point with an identical value at the average position of the milling tool. Recently, a composite material for CAD/CAM has been newly introduced.

This material may have different deflection behaviour from the other materials for CAD/CAM. The purpose of the present study is to investigate the deflection of the newly introduced composite material for CAD/CAM.

MATERIALS AND METHODS

Rectangular specimens with four different sizes (3x3x20mm, 5x5x20mm, 8x8x20mm, and 13x13x20mm) as showed in table 1 were prepared from a newly introduced composite for CAD/CAM (GC Corp, Tokyo, Japan). Each group consists of five light colored preforms (A2) and five dark colored preforms (B3). The specimen was subjected to three point flexural test, using a universal testing machine (Autograph DSS-5000, Shimadzu Ltd, Japan) with an extensometer at a support distance of 15 mm and cross-head speed of 1mm/min. The force and deflection were recorded on a chart . From the chart , the deflection under 500gf was obtained. The data were analysed using two-way ANOVA and a multiple comparison test.

RESULT AND DISCUSSION

Tables 2 and 3 show the summaries of the deflection under 500gf of the composites and the results of ANOVA, respectively. No significant difference in the deflection under 500gf was observed between different shades. On the other hand, the size significantly influenced on the deflection, with higher deflection at smaller size, mainly 3x3mm specimen as shows in fig. 1. However, these result were based on the both end support (three point bending) while, some of CAM are using one end support (cantilever bending). Based on the above results, the deflection of the cantilever bending can be estimated by the following equation :

$$\delta d = \frac{Pl^3}{48IE} \quad ....(1)$$

under three point bending

$$\delta c = \frac{Pl^3}{3IE} \quad ....(2)$$

under cantilever bending

Where, δd = deflection under three point bending

δc = deflection under cantilever bending

p = loading

l = length of the specimen

I= Moment of inertia

E= Elastic modulus of the material

From (1) and (2)

$$\delta c = 16\delta d \quad .... (3)$$

from the equation 3, the deflection under one end support would be 16 times higher than the deflection under both end support at the same conditions, which may cause a big problem with the precision of restoration using CAD/CAM especially smaller size specimen. These results should be further investigated on some restorations fabricated using a CAD/CAM machine.

Deformation of the support due to higher pressure exists but is almost constant with a slight deflection. During milling it is necessary never to exceed a certain tool cutting pressure on the preform and always choose a bigger size of support if we want to obtain the precise surface of the CAD modelisation.

SUMMARY

The deflection under 500gf load of the newly introduced composite materials for CAD/CAM were investigated in order to see the deflection behavior of this materials under the load which would occur during milling, which related to the precision of the restoration. For both end support , S specimen (3x3x20mm) induced significantly higher deflection than the others three sizes specimen. M specimen (5x5x20mm) had higher deflection than L (8x8x20mm) and XL (13x13x20mm) specimens, but the values itself were not so high and the difference was much lower than those compared with S specimen. The deflection under one end support would be 16 times higher than deflection under both end support at the same conditions.

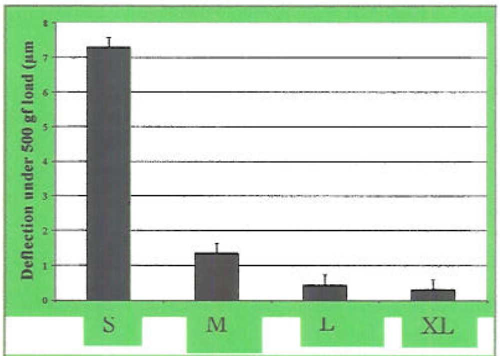


Fig1 : The deflection of the different surface section of the CAD/CAM composite specimen .

Table1 : Size of the specimens (mm)

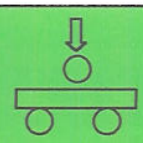
Code	Width	Height	length
S	3	3	20
M	5	5	20
L	8	8	20
XL	13	13	20

Table2 : The deflection under 500gf Load of CAD/CAM composite(μm(SD))

Size	Shade	
	Light	Dark
S	7.30 (0.54)	7.75 (0.38)
M	1.35 (0.05)	1.34 (0.05)
L	0.44 (0.01)	0.45 (0.45)
XL	0.31 (0.03)	0.27 (0.01)

Table 3 : The results of ANOVA

Source	S.S	d.f.	M.S.	fo
A : Shade	0.107	1	0.107	1.94
B :Size	356.500	3	118.833	2153.07
AxB	0.403	3	0.134	2.43
Error	1.766	32	0.055	
Total	589.513	40		



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