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RESEARCH ARTICLE

COMPARATIVE STUDY OF MECHANICAL PROPERTIES OF DIRECT CORE BUILD-UP MATERIALS

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ABSTRACT

Background & Objectives: The strength greatly influences the selection of core material because core must withstand forces due to mastication and para-function for many years. This study was conducted to evaluate certain mechanical properties of commonly used materials for direct core build-up, including visible light cured composite, polyacid modified composite, resin modified glass ionomer, high copper amalgam, and silver cermet cement.

Methods: All the materials were manipulated according to manufacturer's recommendations and Standard test specimens were prepared. A Universal testing machine at different cross -head speed was used to determine all the four mechanical properties. Mean compressive strength, diametral tensile strength, flexural strength, and elastic modulus with standard deviations were calculated. Multiple comparisons of the materials were also done.

Results: Considerable differences in compressive strength, diametral tensile strength, and flexural strength were observed. Visible light cured composite showed relatively high compressive strength, diametral tensile strength, and flexural strength compared to the other tested materials. Amalgam showed highest value for elastic modulus. Silver cermet showed less value for all the properties except for elastic modulus.

Conclusion: Strength is one of the most important criterions for selection of a core material. Stronger materials better resist deformation and fracture provide more equitable stress distribution, greater stability and greater probability of clinical success.

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INTRODUCTION

A core build-up is a restoration placed in badly broken down tooth to restore the bulk of the coronal portion of the tooth to facilitate subsequent restoration by means of an indirect extra - coronal restoration (Combe *et al*., 1994; Saygili and Sahmali, 2002). Compressive and tensile strength of core materials are thought to be important because core usually replace a large bulk of tooth structure and must resist multidirectional forces for many years (Nicholls, 1974; Yetlram *et al*., 1976). Cores are usually retained by pins, posts, and/or bonding system to facilitate their retention, and to restore the tooth to the ext ent to support a crown or bridge (Huysmans and Van derVarst, 1995). Several dental materials have been used for core build-up procedures, some as direct and some as indirect, such as custom cast post and core (Saygili and Sahmali, 2002). The materials used for direct core build-up includes high copper amalgam, visible light cured resin composite, auto cured titanium containing composite, polyacid modified composite, resin modified glass ionomer, and silver cermet cement. Most of these materials were not specially developed for this purpose, but as a consequence of properties such as fluoride release, pleasing colours, adhesion to tooth structure, fast setting rates, choice of curing mechanism, and handling properties, they have found application as core build-up

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procedures (Cattani-Lorente *et al*., 1999; Kerby *et al*., 1997). Although many studies have compared fracture loads of simulated cores in various geometric configurations often on extracted teeth, the strength of core materials have rarely been compared (Combe *et al*., 1994; Saygili and Sahmali, 2002; Nicholls, 1974; Arcoria *et al*., 1989). In view of the development of newer materials in the market, clinician often has uncertainties regarding the choice of best materials to achieve optimum results. A comparative evaluation of mechanical properties of direct core -build materials would help the clinician to choose better products.

MATERIALS AND METHODS

Materials

Details of all five materials are given in (Table 1). This list includes two composite materials specifically developed as core build up material (Z-100 Restorative and Dyract) and one of the most commonly used material in clinical practice resin modified GIC (Vitremer). The two other products were a silver cermet (Hi-Dense XP) and silver amalgam (shofu).

Properties measured

The specimen dimensions for each property were selected according to ISO 4049 (international standards organization, 1992). Compressive strength and diametral tensile strength were measured for cylindrical specimens, 3x6 (d.h.). Flexural strength and Elastic modulus were measured for rectangular specimens, 25x2x2 (l.b.h.). Specimens were stored at 37±1°C prior to testing. Ten specimens were made and tested for each group. Data were analyzed by Kruskal Wallis test and Mann-Whitney ‘U’ test, with statistical package for social science (SPSS) version 11.5 for windows.

Measurement of properties

All tests were carried out on an Instron universal testing machine (Series IX, model 1011, UK). Compressive and flexural strength were determined at a-cross head speed of 0.5 mm/min. diametral strength was carried out at 1mm/min. Diametral tensile strength was calculated from the formula

$$T = 2F/\pi DL$$

Where F is the maximum applied load (N); D is the mean diameter of the specimen (mm) and L the length (height) of specimen (mm).

Flexural strength was calculated from the following equation:

$$\sigma = 3Fl/2bh^2$$

where F is the maximum load exerted on the specimen; *l* is the distance (mm) between the supports ± 0.01 mm; *b* is the width (mm) *of* specimen immediately prior to testing; and h is the height (mm) *of* specimen measured immediately prior to testing. The experimental variables of specimen size, shape, testing configuration, fabrication procedure, temperature, humidity, storage time, storage temperature, strain rate, and set time were all standardized in this study. All specimens were treated identically throughout this study, which was based on ADA Specification No. 27. Thus, comparisons among materials were appropriately made. In this study, core materials were compared at a single short setting time, but various types of material differ in their setting mechanisms. Some materials, such as glass ionomers, continue to mature for extended periods. Thus, the comparison was valid only for the 24-hour setting time. However, cores may have to resist loads soon after placement, the effects of increased curing over time are small in comparison to the large differences among materials, and established specifications recommend 24-hour test times.

RESULTS

Statistical analysis for the strength of core materials was performed, and the mean valve with its standard deviation was calculated for each material. The Kruskal Wallis test (H) and Mann-Whitney ‘U’ TEST (Z), with statistical package for social science (SPSS) version 11.5 for windows was used. Here the Kruskal Wallis test (H) was used to compare the four properties for each material. The Mann -Whitney ‘U’test was used for multiple comparison of four properties among five different materials and the significance was found at 5% confidence level. Compressive strength, elastic modulus, diametral tensile strength, flexural strength data and results of the statistical analysis data are given in (Table 2, 3, 4, 5). Compressive strength, diametral tensile strength, flexural strength and elastic modulus varied among different core build-up materials. Visible light cured composite (Z-100) had relatively high compressive strength, diametral tensile strength, and flexural strength compared to the other tested materials. The compomer (Dyract) and resin modified glass ionomer (Vitremer) showed good mechanical properties except in terms of elastic modulus. Amalgam (Hi-Aristaloy) showed highest elastic modulus value compared to the other materials tested. Cermet glass ionomer (Hi-dense) showed less value for all the mechanical properties except in terms of elastic modulus (Table 6).

Table 1. Materials used for study

Sl. No.	Product	Manufacturer	Material type	Batch No
1	Z-100 Restorative	3M ESPE Dental Products	Visible light cured composite	20040706
2	Dyract	Dentsply De Trey Gm bH	Polyacid modified composite (Compomer)	6064204
3	Vitremer	3 MESPE AG Dental products Seefeld-Germany	Resin modified glass ionomer cement	20040329
4	Hi-Aristaloy	Heesung Engelhard Corp	Amalgam	232
5	Hi-Dense XP	Shofu Dental Corporation	Silver cermet cement	020406-51

DISCUSSION

Considerable differences in compressive and diametral tensile strengths were discerned among core materials. The strongest material was 2 times stronger than the weakest material in compression, and 3 times stronger in dimetral tension and 4 time stronger in flexural strength (Fig. 1).

Table 2. Comparison of compressive strength

Product	Mean	SD	H	P
(n=8)	(MPa)			
Z-100	122.25	36.78		
Dyract	114.27	17.14		
Vitremer	109.13	16.18	20.56	0.001 vhs
HI-Aristaloy	74.29	25.65		
HI-Dense	64.63	24.92		

Table 3. Comparison of diametral tensile strength

Product	Mean	SD	H	P
(n=8)	(MPa)			
Z-100	47.62	8.19		
Dyract	29.62	9.98		
Vitremer	18.58	3.04	28.20	0.001 vhs
HI-Aristaloy	24.12	4.34		
HI-Dense	17.45	3.20		

Table 4. Comparison of flexural strength

Product	Mean	SD	H	P
(n=5)	(MPa)			
Z-100	128.07	32.81		
Dyract	97.42	6.89		
Vitremer	58.73	9.98	18.96	0.001 vhs
HI-Aristaloy	36.40	21.62		
HI-Dense	45.70	9.88		

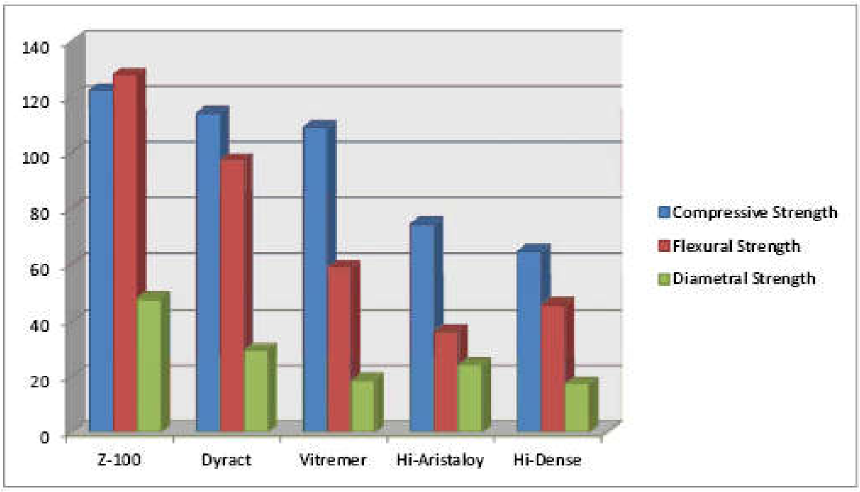
Table 5. Comparison of elastic modulus

Product (n=5)	Mean (GPa)	SD	H	P
Z-100	16.44	7.14		
Dyract	10.81	0.97		
Vitremer	11.86	1.41	8.76	0.067hs
HI-Aristaloy	17.28	3.93		
HI-Dense	16.49	2.87		

Such large difference might reasonably be expected to have clinical significance. Minimum strength needed for core materials are unknown, but many of materials tested did not meet the dimetral tensile strengths required by the American Dental Association Specifications for direct filling resins (24 and 34 MPa for type I and type II materials, respectively (Programs of the Council on Dental Materials, 1977). Compressive strength is considered to be a critical indicator of success because a high compressive strength is necessary to resist masticatory and parafunctional forces (Grorge C. Cho *et al.*, 1999; Miyawaki *et al.*, l993). Tensile strength is important because dental restorations are exposed to tensile stresses from oblique or transverse loading of their complex geometric forms. Diametral tensile testing is a common method for measuring tensile strength of brittle materials because it avoids some of the difficulties inherent in direct and flexural tensile testing (Levartovsky *et al.*, 1994; Huysmans *et al.*, 1992). Amalgam has been considered to be the material of choice for cores. Both mechanical tests and Finite element analyses have indicated that amalgam cores have superior performances in comparison to resin composite cores (Huysmans and Van derVarst, 1995; Huysmans and Van der Varst, 1993; Kovarik *et al.*, 1992). In fatigue testing, amalgam cores have deformed less, produced smaller marginal gaps and applied lesser stresses to tooth structure than resin composite cores (Huysmans and Van der Varst, 1993; Kovarik *et al.*, 1992; Huysmans and Van derVarst, 1995). Amalgam cores are certainly to be preferred to glass ionomer, resin-modified glass ionomer, or glass ionomer cermet cores (Miyamoto *et al.*, 1989; Dewald *et al.*, 1990; Arcoria *et al.*, 1989). The dark colour of amalgam may not be aesthetic, but it is easy to differentiate from tooth structure during tooth preparation (Netti *et al.*, 1988). Unfortunately, the relatively slow set of amalgam delays rotary preparation of

Table 6. Multiple comparison of compressive strength, diametral strength, flexural strength and elastic modulus

	Compressive		Diametral		Flexural		Elastic modulus	
Products	Z	P	Z	P	Z	P	Z	P
Z-00 Vs Dyract	0.420	0.674	2.856	0.005	1.567	0.117	0.522	0.602
Z-00 Vs Vitremer	0.525	0.600	3.361	0.001	2.611	0.009	0.522	0.602
Z-00 Vs Hi-Aristaloy	2.731	0.006	3.361	0.001	2.611	0.009	0.313	0.754
Z-00 Vs Hi-Dense	2.731	0.006	3.361	0.001	2.611	0.009	0.313	0.754
Dyract Vs Vitremer	.000	1.000	2.836	0.005	2.611	0.009	1.149	0.251
Dyract Vs Hi-Aristaloy	2.731	0.006	1.050	0.294	2.611	0.009	2.402	0.016
Dyract Vs Hi-Dense	2.941	0.003	3.046	0.002	2.611	0.009	2.611	0.009
VitremerVs Hi-Aristaloy	2.941	0.003	2.310	0.021	1.567	0.117	1.984	0.047
Vitremer Vs Hi-Dense	3.046	0.002	0.840	0.401	1.358	0.175	2.611	0.009
Hi-AristaloyVsHi-Dense	0.735	0.462	2.626	0.009	0.838	0.402	0.522	0.602



Graph 1. Comparative evaluation of comprehensive strength, flexural strength and diametral strength among various core build up materials

amalgam cores and has limited its use. However Developments and advances in non-y_2 amalgams and the new concepts of bonding dental amalgam to tooth structures have helped to ensure that amalgam remains one of the materials widely used for core build up procedures in posterior teeth (Varga *et al*., 1986; Staninec, 1989). Glass-ionomer based materials were markedly weaker than the resin composite and amalgam materials (Tables 2 and 3). Although some mechanical properties of resin-modified glass-ionomer materials only deteriorate slowly over time, the dimensional stability of resin modified materials can be poor (Cooley *et al*., 1990; Mitra and Kedrowski, 1994; Nicholson *et al*., 1992). Sliver 'reinforcement" did not improve the strength of Hi-dense Silver glass ionomer in comparison to a conventional glass ionomer. Although some mechanical properties of glass ionomer and resin-modified glass ionomer materials only deteriorate slowly over time, the dimensional stability of resin-modified materials can be poor (Nicholson *et al*., 1992; Anstice and Nicholson, 1992). Glass ionomers are also less fatigue-resistant than resin composites (Miyamoto *et al*., 1989); thus, the role of glass ionomers and glass ionomer based materials as cores must be questioned.

The results of our study indicate that, on the basis of strength alone, some resin composites may be used as alternative to amalgam cores. Resin composites have several practical advantages. They can be translucent and tooth-coloured, thus, they do not darken teeth. They can also be selected for colour contrast against tooth structure, to facilitate tooth preparation for crowns. They can be bonded to teeth using dentinal adhesives. For convenience, either light initiated or auto - curing materials can be selected. As they set quickly, core and tooth preparations can be completed using rotary instrumentation without delay (Grorge *et al*., 1999; Miyawaki *et al*., l993). However, resin composites also have some disadvantages. Light-cured materials may not undergo complete curing if insufficient light intensity or curing time is used, too great a thickness is applied, or if they are reaching the end of their shelf lives. Although excellent adhesion to tooth structure can be achieved with dentinal bonding agents, the long-term stability of such bonds is unknown (Grorge *et al*., 1999; Miyawaki *et al*., l993; Tjan *et al*., 1993; Tam *et al*., 1991). Resinous materials may be less physically and dimensionally stable than amalgam. Sorption of water, after impression making and before casting cementation, can compromise seating (Arcoria *et al*., 1989; Oliva and Lowe, 1986). One crown retention study showed that crowns cemented to resin composite cores were more retentive than crowns cemented to similar amalgam cores (DeWald *et al*., 1987). That result could be attributed to slight swelling of the composite resulting in tighter fitting castings. Alternatively differences in core surface roughness might account for that finding.

Conclusion

Strength is not only one criterion for selection of core material, but it is crucial. Stronger core materials better resist deformation and fracture provide more equitable stress distributions, reduced probability of tensile or compressive failure, greater stability, and greater probability of clinical success. If other parameters are considered to be equal, the strongest core material is indicated. Although the perfect core material does not yet exist, the results of our study and other prior studies indicate that both amalgam and resin composites may be indicated for use as core materials in specific clinical situations.

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