Short Communication

Strength Investigation of Artificial Substitutes for Human Teeth in In Vitro Studies

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This study investigated whether metals or resins can replace human teeth in in vitro fracture tests of endodontically treated teeth (ETT), as ETT show high heterogeneity and small availability. Eight incisor-shaped roots per group were adhesively restored with fiber-reinforced composite posts, composite core build-ups and Co-Cr-Mo crowns. Specimens were thermally cycled and mechanically loaded (TCML) and fracture strength was determined. The results varied between 0 N and 348 N. Extracted ETT may show comparable strength and survival during TCML to teeth in situ and therefore are the first choice for in vitro testing. Substitutes show comparable fracture patterns but different fracture values. *Int J Prosthodont 2009;22:62–64.*

Human teeth possess high tooth heterogeneity, have minimal availability (especially anterior teeth), and are strongly influenced by storage times.[1] For these reasons, as well as many others, studies conducted to examine human teeth have yielded results that show a broad standard of deviation from one another.[2,3] This might also be the reason why many studies have encompassed a similar set-up to this one, but instead are used to answer another research question.[4] Therefore, being able to substitute the complex structure of a human tooth and its vast variability with a more uniform substance or material is an important step towards the standardization of in vitro tests. Obviously artificial teeth[2,5] would be a great advantage in terms of available specimen numbers, the standardization of tooth dimensions, or the reduced variability of their biomechanical behavior. Substitute materials like alloys or resins, for example, show strong differences in stiffness or elastic modulus and may therefore influence the behavior of the tooth under load.[5] The aim of this investigation was to compare the fracture force and fracture pattern of different artificial materials to that of human teeth. The hypothesis was that artificial teeth may be used as tooth substitutes for in-vitro fracture testing.

Materials and Methods

The crowns of 8 resin incisors (tooth 11, Morita; group 1) were cut 2 mm coronal to the cementoenamel junction and prepared with a 1-mm-deep chamfer finishing line. This model was used as a standard to fabricate identical models of the following materials: Co-Cr alloy (group 2, Adorbond, Ador), 2 laboratory-fabricated veneering composites: Adoro (group 3, Ivoclar-Vivadent) and Belleglass (group 4, Kerr), PMMA (group 5, Palapress, Heraeus-Kulzer), embedding conserve

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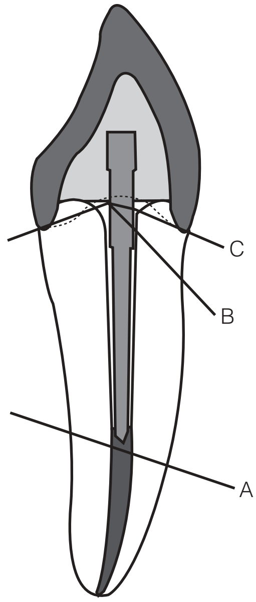

Table 1 Frequency of Fracture Types (n = number of fractures observed)

Group	Material	Fracture Type*		
		A	B	C
1	Anatomic tooth (J. Morita)	3	5	
2	Co-Cr alloy (Adorbond CC)			8
3	SR Adoro (veneering composite)	1	7	
4	Belleglass HP (veneering composite)	1	7	
5	PMMA (Palapress Vario Transparent)	4	4	
6	XOR-Crystal (molding resin)	2	5	1
7	Presto-flex (polyester filling compound)	3	5	
8	Rencast CW 2215 (epoxy resin)		6	2
Control	Human tooth			8

*Refer to Fig 1.

Fig 1 Fracture patterns: **(A)** root fracture, **(B)** fracture line facially within the root, and **(C** fracture line along the finishing line.

resin XOR-Crystal (group 6, Xenophile Operations Resistance, Glorex), car-repair resin presto-flex (group 7, Motip Dupli), and epoxy resin (group 8, Rencast). Human incisors of a size similar to the Morita teeth were used as a control group. The root canals of all teeth and substitute teeth (n = eight per group) were enlarged using Hedström files (sizes 15 to 40, Roeko, Langenau) and filled with gutta-percha points (Dentsply Maillefer, Ballaigues) and sealer (AH Plus, Dentsply DeTrey). After 24 hours, post preparation was performed (FRC post steel reamer; length: 10 mm; Ivoclar-Vivadent). Fiber-reinforced posts (Postec, Ivoclar-Vivadent) were luted using a matching bonding system (Syntac Classic, Ivoclar-Vivadent) and dual-curing composite resin cement (Variolink II, high viscosity, Ivoclar-Vivadent). Standardized composite cores (Tetric Ceram, Ivoclar-Vivadent) were adapted and Co-Cr-Mo crowns (occlusal-gingival height: 9 mm) were adhesively luted (Syntac Classic/Variolink II, Ivoclar-Vivadent). The periodontal ligament was simulated by covering the roots of all teeth with a 1-mm-thick layer of polyether (Impregum, 3M ESPE). The specimens were thermally cycled (6,000 × 5°C/55°C, distilled water, 2 min each cycle) and mechanically loaded ($1.2 \times 10^6 \times 50$ N) (TCML), and finally loaded to fracture (v = 1 mm/min; angle: 135 degrees, Zwick). Specimens that failed during TCML were assigned a fracture force value of "0". Types of failure were analyzed and categorized in three modes (Fig 1), of which the most frequent fracture seen was along the finishing line palatally and within the root facially, followed by apical fractures (Table 1). Statistical analysis was done by Mann-Whitney *U* test ($\alpha = 0.05$).

Results

The highest median fracture resistance (Fig 2) was found for the nonprecious alloy substitute (348 N), followed by the human incisor control (158 N), and both veneering composites (Belleglass: 183 N; Adoro: 117 N). Significantly lower median results could be determined for the resin Morita teeth (56 N), the XOR-Crystal substitutes (87 N), and the epoxy resin abutments (0 N). All specimens of the PMMA and polyester groups, 4 specimens of the Morita group, 6 specimens of the epoxy group, and 1 each of the nonprecious alloy and XOR-crystal groups failed during TCML. The smallest differences ($P = .77$) were found between the human incisors and the Belleglass composites. The main failure was fracture along the finishing line palatally and within the root facially. This was followed closely by apical fractures (Table 1). All human incisors and Co-Cr abutments depicted fracture along the finishing line, as well as 2 epoxy teeth and 1 XOR-Crystal tooth. Detailed statistical information is provided in Table 2.

Discussion

In contrast to our expectations, a lower deviation of the results could not be achieved using substitute materials. By increasing the sample size, significant differences were supposed to be emphasized. Only Morita, Adoro, Belleglass, and the Co-Cr alloy showed no significantly different fracture resistance when compared to human teeth and may therefore be considered suitable substitute materials.

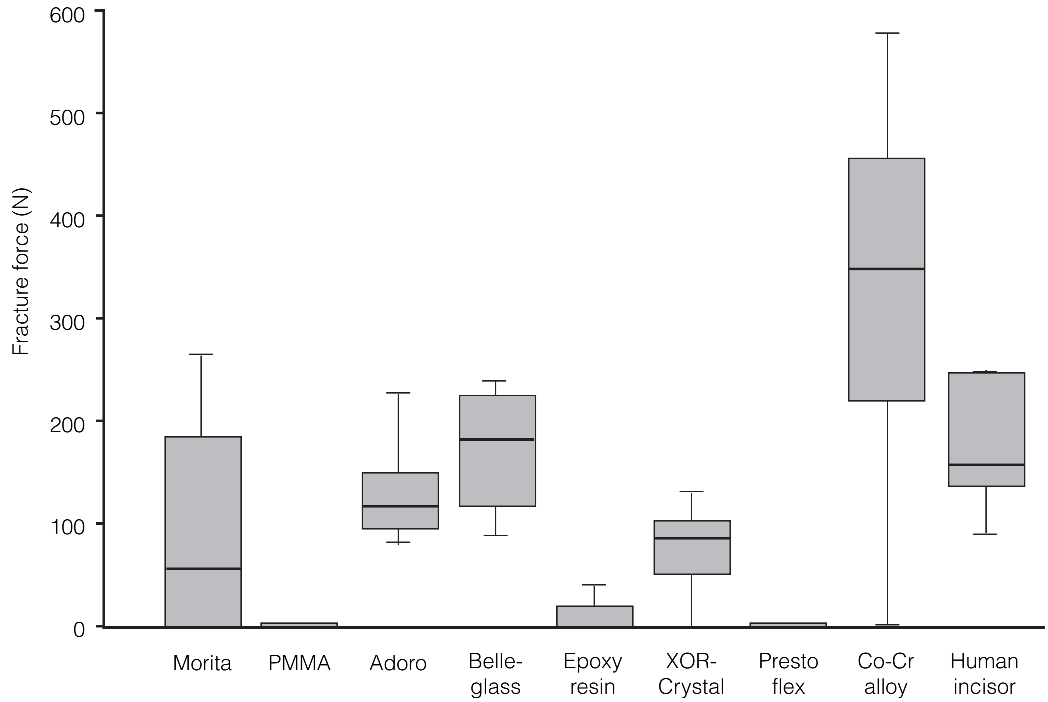

Fig 2 Failure load (N) per group (median values = bold lines; 25%/75%).

Table 2 Pairwise Comparison of Median Fracture Values* with Mann-Whitney *U* test and *P* values

	Morita	Adoro	Belleglass	Epoxy resin	Co-Cr alloy	XOR-Crystal
Adoro	0.491					
Belleglass	0.139	0.128				
Epoxy resin	0.184	0.004	0.001			
Co-Cr alloy	0.014	0.027	0.059	0.004		
XOR-Crystal	0.915	0.036	0.001	0.037	0.014	
Human tooth (control)	0.235	0.143	0.77	0.006	0.107	0.013

*Polyester and PMMA specimens failed during TCML and were therefore given a fracture force of “0” and not calculated.

Conclusion

Extracted teeth show comparable properties to teeth in situ and therefore may be the first choice for in vitro fracture testing. Substitute materials provide information about fracture patterns, but they are not an alternative when taking fracture values into consideration.

References

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