Energy Dissipation and Damping Behavior of Commonly Used CAD/CAM Materials

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1. Objectives

Loss of periodontal ligament causes implant-supported restorations to be vulnerable to occlusal overloading by high impact energy from mastication. Shock absorption and damping capacities of CAD/CAM milling materials (MM) are supposed to be relevant parameters to prevent implant overstressing and provide material robustness and long-term survival [1-3]. Only little information is available about resilient and tough material behavior of MM [4].This study compares the capacities of different MM to dissipate destructive fracture energy by elastic and plastic material deformation in comparison to human wet enamel.

2. Materials & Methods

Fourteen commercially available MM were investigated (Tab 1). Four ceramic **(C)**, seven hybrid composite **(HC)** and three polymer **(P)** materials. As reference materials a gold alloy (BH) and a wet natural tooth surface (NT) were included in the investigation. A precision saw (IsoMet™ 1000, Buehler) with a diamond coated water-cooled sawblade was used to cut disks (n=2, 14.0x12.0x3.5±0.5 mm³) from each machinable block for Leeb hardness **(HL)** testing (EQUOTIP BAMBINO2; Impact body type D; ISO 16859 [5]) (Fig. 1). All measuring surfaces of the specimen were polished on wet SiC abrasive paper (800 grit; Leco Corp). Testing was carried out (n=5x2) on a 50-mm thick granite base (Fig. 1) at ambient laboratory conditions (23 ± 1°C; 50 ± 5% relative humidity) without previous water storage. NT was tested in a wet state. Kinetic energy was determined by measuring the impact velocity **(V_I)** and rebound velocity **(V_R)** of the impact body (Fig. 2) to calculate HL via HL=V_R/V_I • 1000 [5-8]. Impact surfaces were investigated by using an optical profilometer (MicroProf, Fries Research & Technology GmbH, Germany) with the corresponding software (Mark III). Data were analyzed by One-way ANOVA and Games-Howell post-hoc test (p< .05) to identify significant differences between MM.

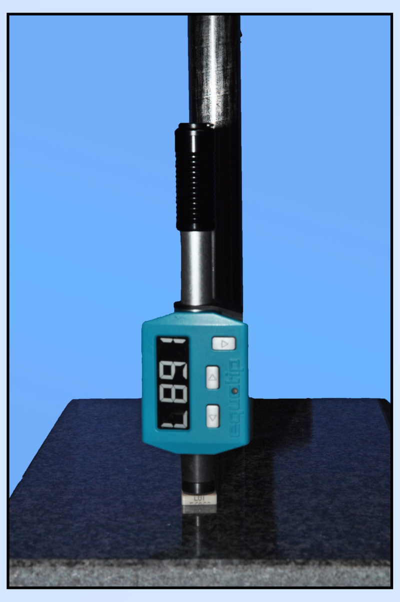

Fig. 1: Equotip Bambino2.

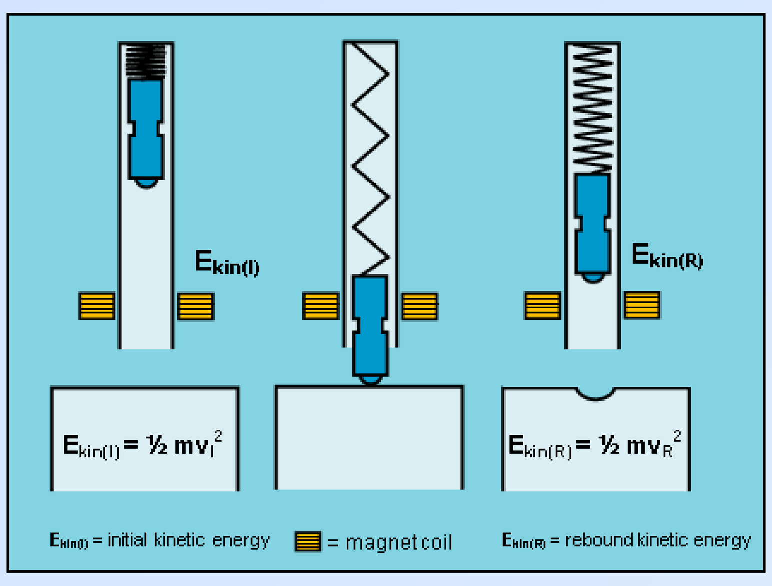

Fig. 2: Schematic drawing of the Leeb rebound test.

Milling Material		*Manufacturer*	*Lot*	*Shade*	*Material Type*	
Vitabloc Mark II	**(VM)**	Vita Zahnfabrik	37480	A2C	Feldspathic Ceramic	C
Celtra Duo	**(CD)**	Dentsply Sirona	18025791	A2 LT	Lithium disilicate glass ceramic	C
BruxZir	**(BZ)**	Glidewell	BZ0010186	A2	Zirconia	C
IPS e.max CAD	**(IPS)**	Ivoclar Vivadent	W05269	A2 HT	Lithium disilicate glass ceramic	C
Vita Enamic	**(VE)**	Vita Zahnfabrik	38910	2M2HT	Hybrid Composite	HC
Lava Ultimate	**(LU)**	3M ESPE	N880844	A2 LT	Hybrid Composite	HC
Grandio blocs	**(GB)**	VOCO	1715234	A3 HT	Hybrid Composite	HC
Shofu Block	**(SB)**	SHOFU Dental	021501	A2 LT	Hybrid Composite	HC
Cerasmart	**(CS)**	GC Group	1512021	A3 HT	Hybrid Composite	HC
Ambarino High-Class	**(AHC)**	Creamed	160117	A2	Hybrid Composite	HC
Brilliant Crios	**(BC)**	Coltène/Whaledent	H82105	A2	Hybrid Composite	HC
Telio CAD	**(TC)**	Ivoclar Vivadent	23170	1M2T	Polymethyl-methacrylate	P
M-PM disc	**(MPM)**	Merz Dental	31231	A2	Polymethyl-methacrylate	P
Juvora PEEK Optima	**(J)**	Juvora Ltd	J000025	——	Polyetheretherketone	P
Bio Herador N	**(BH)**	Kulzer	36513	——	Gold alloy#	—
Natural Tooth	**(NT)**	Human Third Molar	——	——	Wet Enamel	—

Tab 1 Investigated CAD/CAM materials. # (Au: 86.2 %, Pt: 11.5 %, Zn: 1.5 %) C, ceramic; HC, hybrid composite; P, polymeric resin.

3. Results

While the significantly highest HL values were detected for VM which implied only a marginal damping effect, the lowest HL results and therewith the highest energy dissipation and damping capacity was received for BC among the investigated MM (Fig. 3). The reference materials BH and NT showed even lower HL values than BC and therewith superior damping behavior. HC and P generally disclosed significantly lower HL results than C. While the impact body left indentions on the BC, J and BH surfaces, resulting from plastic deformation, no surface dents could be detected for VM (Fig. 4).

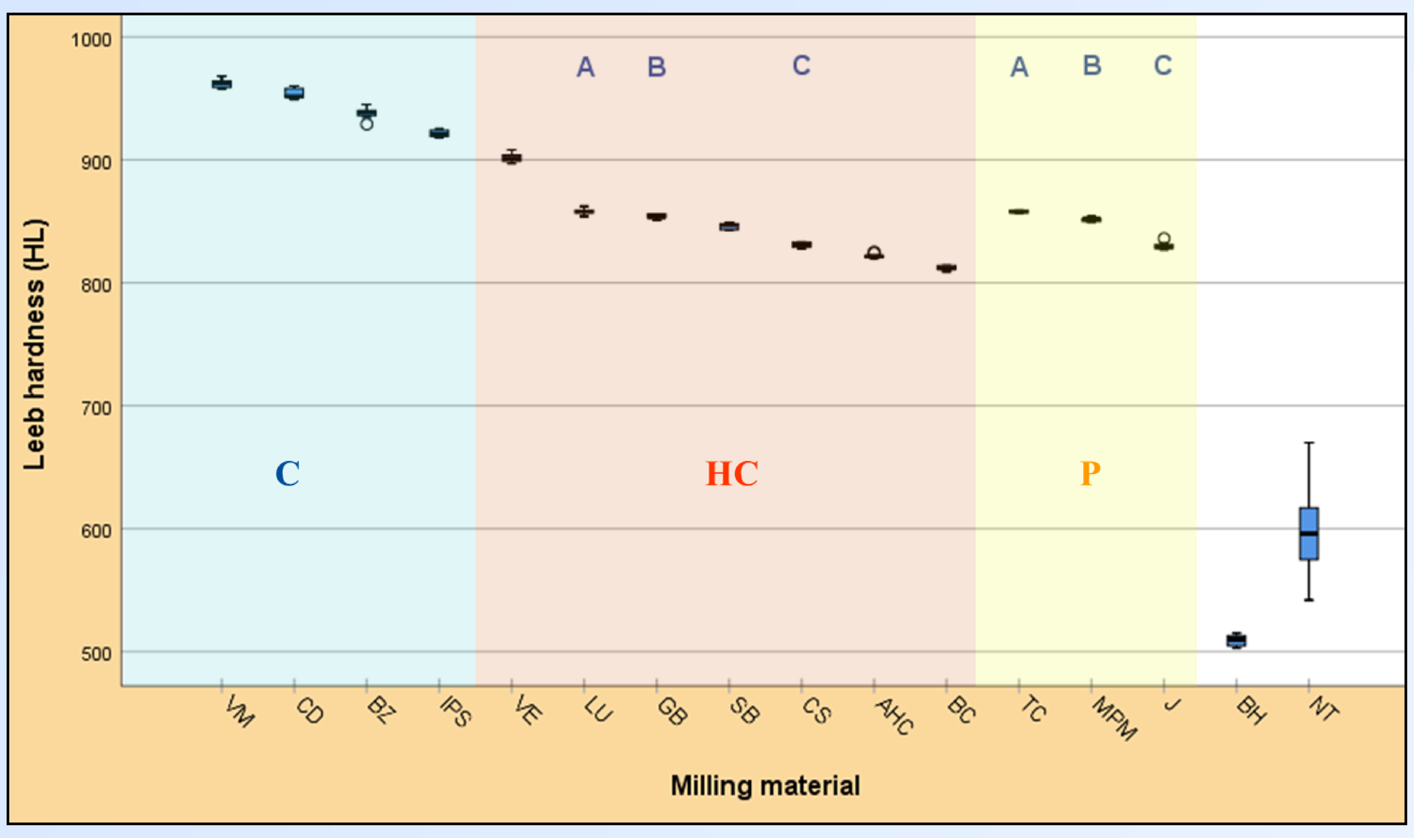

Fig. 3: Leeb hardness; same bold letters denote material groups with no significant difference.

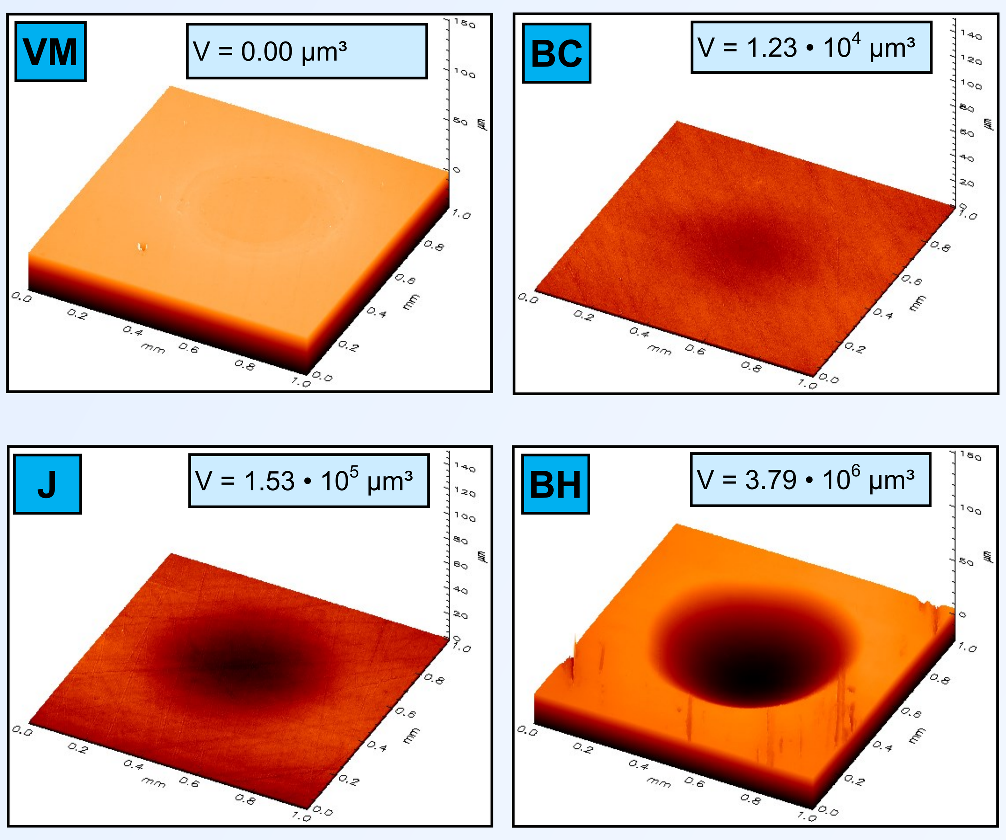

Fig. 4: Microtopography and indention volume of impact areas

4. Discussion & Conclusion

The amount of kinetic energy that has not been recovered by the indenter after the impact phase has unequivocally been used to elastically and plastically deform the investigated specimen as well as the impact body [8]. While for the indenter plastic deformation can be neglected because of its high material hardness [5,8], this kind of energy dissipation that strongly depends on the chemical nature of the investigated material occurs in combination with elastic deformation on the surface of the test specimen. For VM $E_{kin(I)}$ is almost completely recovered as $E_{kin(R)}$ because no plastic surface deformation could be detected (V=0.00 µm^3) (Fig. 4) and only little energy was dissipated elastically, both resulting in poor damping behavior. In contrast, J shows a high amount of plastic energy dissipation with a considerable indention on the specimen surface (V=1.53•10^5 µm^3) (Fig. 4) revealing significantly higher damping capacities. Although BC shows a lower HL value than J and therewith a higher damping effect, more energy is dissipated elastically than plastically as the indention on the surface is significantly lower (V=1.23•10^4 µm^3) when compared with J (Fig. 4). BH shows the highest damping capabilities as a result of a high degree of plastic energy dissipation which is demonstrated by the highest indention volume (V=3.79•10^6 µm^3). As a result MM belonging to the HC and P group seem to be very promising to achieve damping capacities matching as close as possible to natural tooth properties.

5. References

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