NANOVEA
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TOOTH HARDNESS EVALUATION

USING

NANOINDENTATION

Prepared by

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Introduction

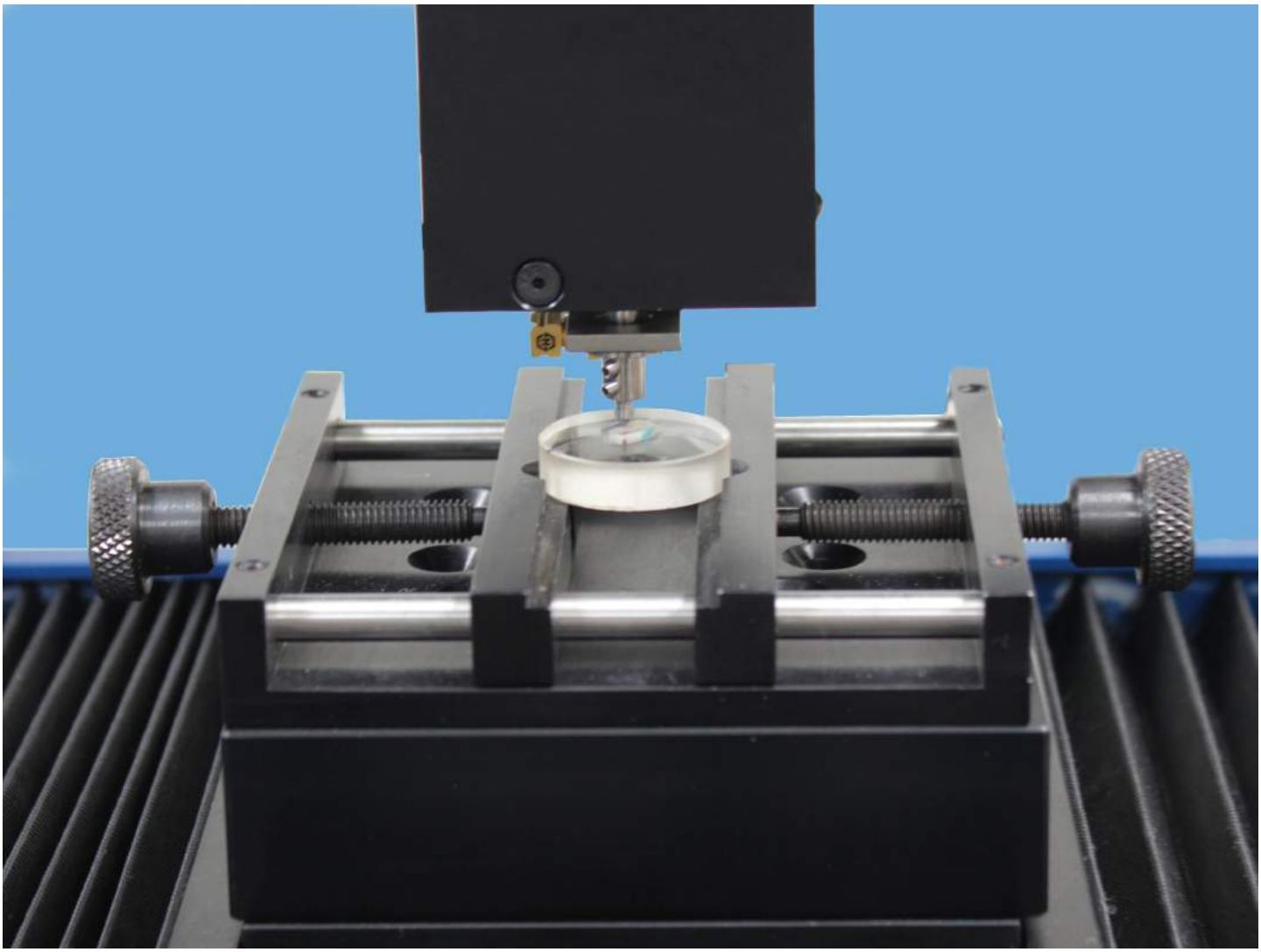
Biological material that has naturally developed over time is the inspiration for many new material developments. These biological materials of interest are made up of complex organic and inorganic structures resulting in superior mechanical properties. To reproduce a high-performance man-made version will require comparable properties. It is thus critical to understand, control and evaluate the fabrication of these bio-inspired materials for intended mechanical property results.

Importance of Nanoindentation for Biomaterials

With many traditional mechanical tests (Hardness, Adhesion, Compression, Puncture, Yield Strength, etc.), today's quality control environments with advanced sensitive materials, from gels to brittle materials, now require greater precision and reliability control. Traditional mechanical instrumentation fails to provide the sensitive load control and resolution required; designed to be used for bulk materials. As the size of material being tested became of greater interest, the development of Nanoindentation provided a reliable method to obtain essential mechanical information on smaller surfaces such as the research being done with biomaterials. The challenges specifically associated with biomaterials have required the development of mechanical testing capable of accurate load control on extremely soft to brittle materials. Also, multiple instruments are needed to perform various mechanical tests which can now be performed on a single system. Nanoindentation provides a wide range of measurement with precise resolution at nano controlled loads for sensitive applications.

MEASUREMENT OBJECTIVE

In this application, the Nanovea Mechanical Tester, in Nanoindentation mode, is used to study the hardness and elastic modulus of the dentin, decay, and pulp of a tooth. The most critical aspect with Nanoindentation testing is securing the sample, here we took a sliced tooth and epoxy mounted leaving all three areas of interest exposed for testing.



Sample of tooth being anaylzed with the Nanovea Mechanical Tester

TEST CONDITIONS

	All Samples
Maximum force (mN)	30
Loading rate (mN/min)	60
Unloading rate (mN/min)	60
Creep (s)	20
Computation Method	Nanovea
Indenter type	Berkovich Diamond

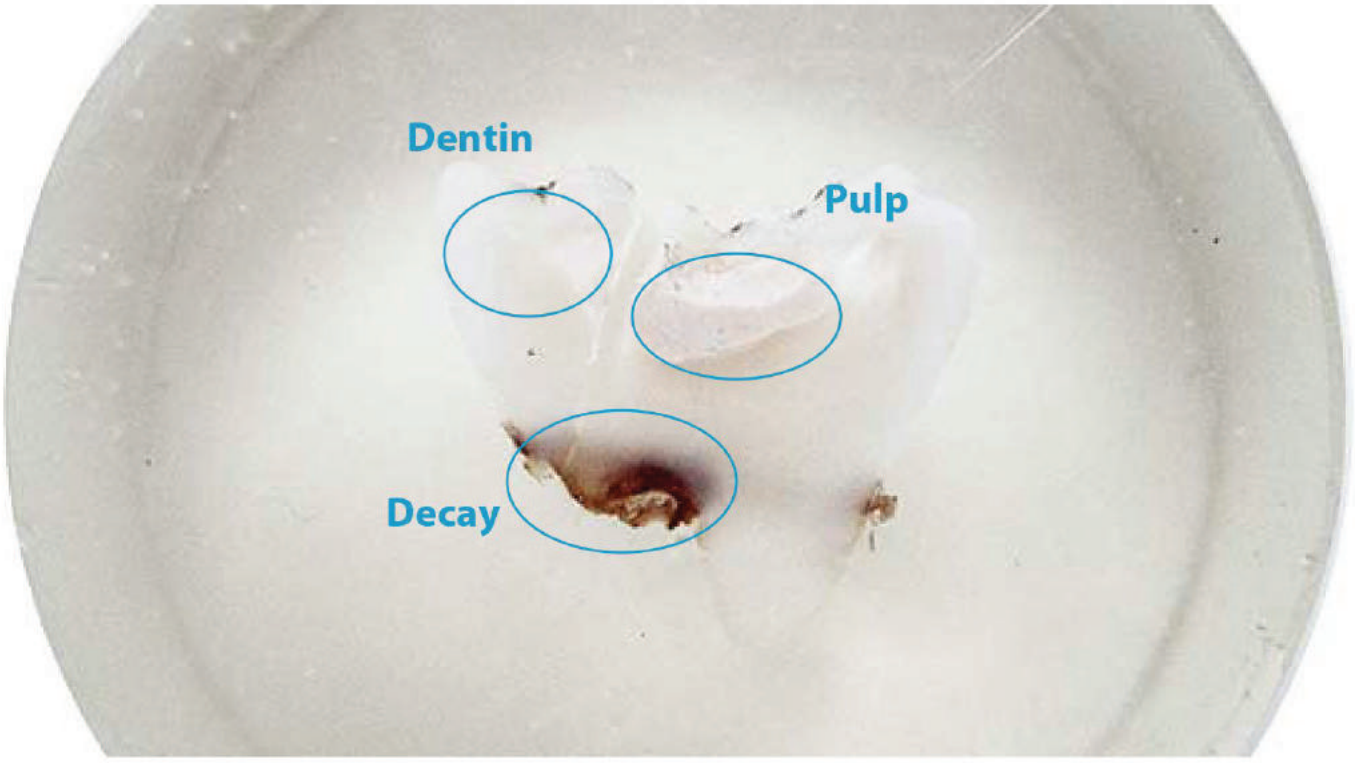
Sample of tooth used for testing

RESULTS AND DISCUSSION

This section includes a summary table that compares the main numerical results for the different samples, followed by the full result listings, including each indentation performed, accompanied by micrographs of the indentation, when available. These full results present the measured values of Hardness and Young's modulus as the penetration depth with their averages and standard deviations. It should be considered that large variation in the results can occur in the case that the surface roughness is in the same size range as the indentation.

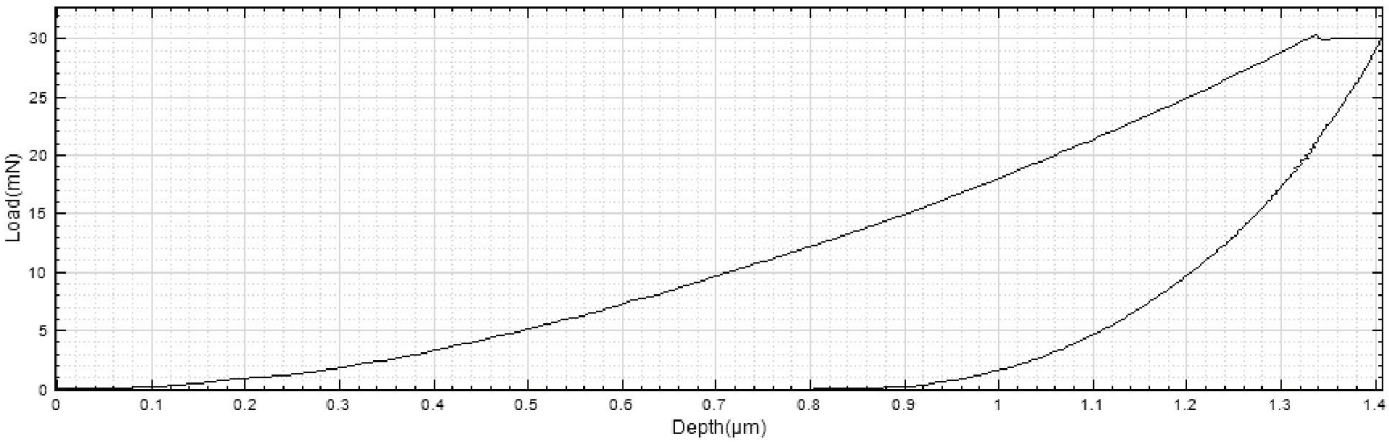
Summary table of main numerical results:

Sample	Hardness [Vickers]	Hardness [GPa]	Young's Modulus [GPa]	Depth [nm]
Dentin	83.0 ± 3.0	0.878 ± 0.032	17.9 ± 0.5	1360 ± 19
Decay	24.3 ± 5.1	0.257 ± 0.054	4.58 ± 0.47	3329 ± 310
Pulp	20.5 ± 0.3	0.217 ± 0.004	3.49 ± 0.07	3643 ± 32

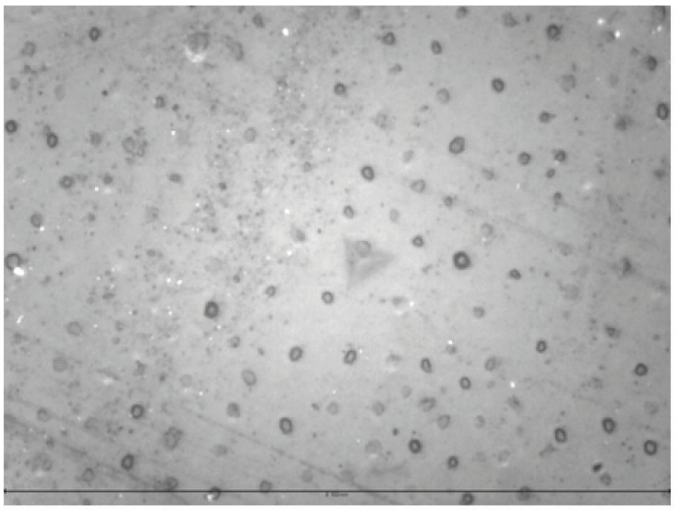


DENTIN

Sample	Hardness [Vickers]	Hardness [GPa]	Young's Modulus [GPa]	Max Depth [nm]
1	20.9	0.221	3.57	3606
2	20.3	0.215	3.44	3668
3	20.4	0.216	3.47	3656
Average	20.5	0.217	3.49	3643
Standard Deviation	0.3	0.004	0.07	32



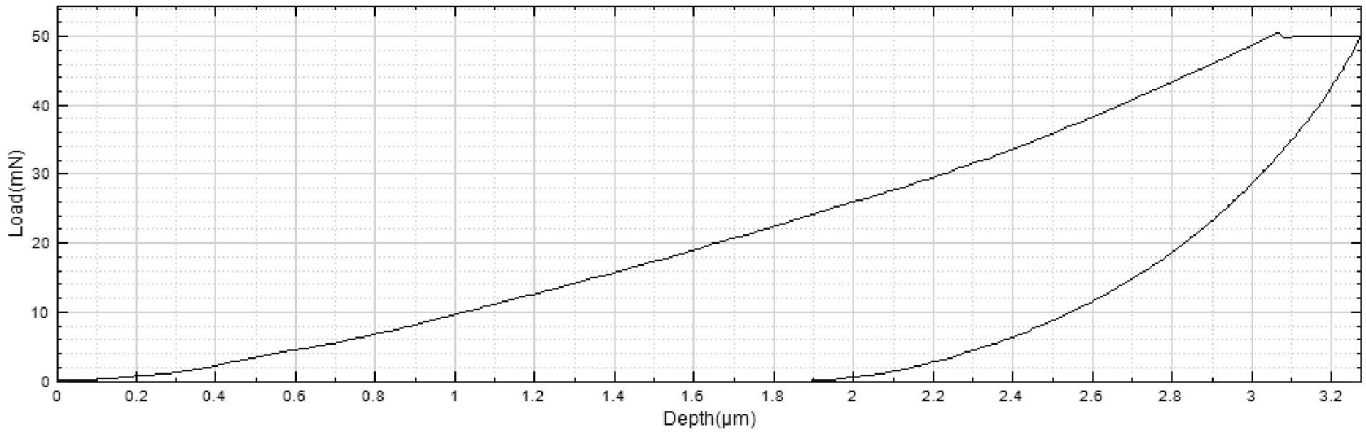
Loading Curve –Dentin, Indent 1



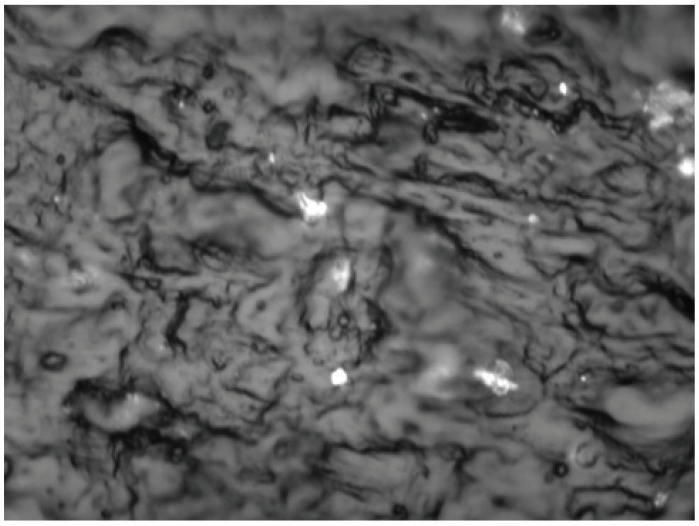
Micrograph of Indent 500X –Dentin, Indent 1

DECAY

Sample	Hardness [Vickers]	Hardness [GPa]	Young's Modulus [GPa]	Max Depth [nm]
1	29.0	0.307	5.07	3054
2	25.0	0.264	4.53	3268
3	18.9	0.200	4.13	3665
Average	24.3	0.257	4.58	3329
Standard Deviation	5.1	0.054	0.47	310



Loading Curve –Decay, Indent 1



Decay Area

PULP

Sample	Hardness [Vickers]	Hardness [GPa]	Young's Modulus [GPa]	Max Depth [nm]
1	20.9	0.221	3.57	3606
2	20.3	0.215	3.44	3668
3	20.4	0.216	3.47	3656
Average	20.5	0.217	3.49	3643
Standard Deviation	0.3	0.004	0.07	32

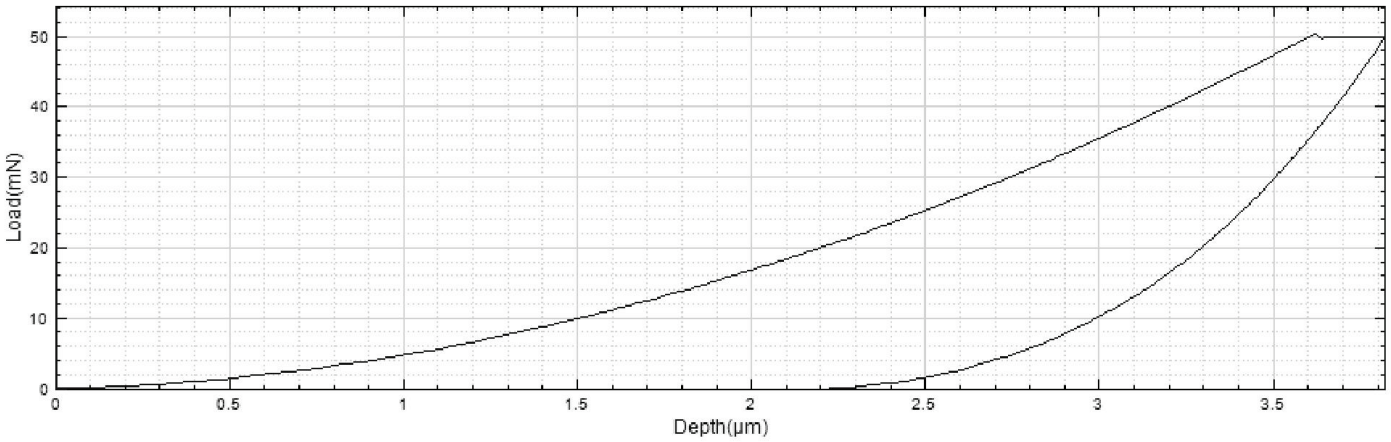
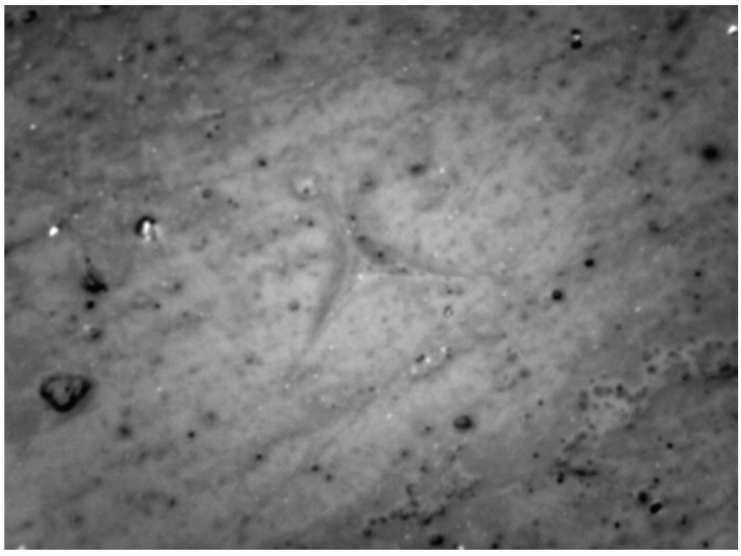


Figure 1: Loading Curve – Pulp, Indent 1



Pulp Indent

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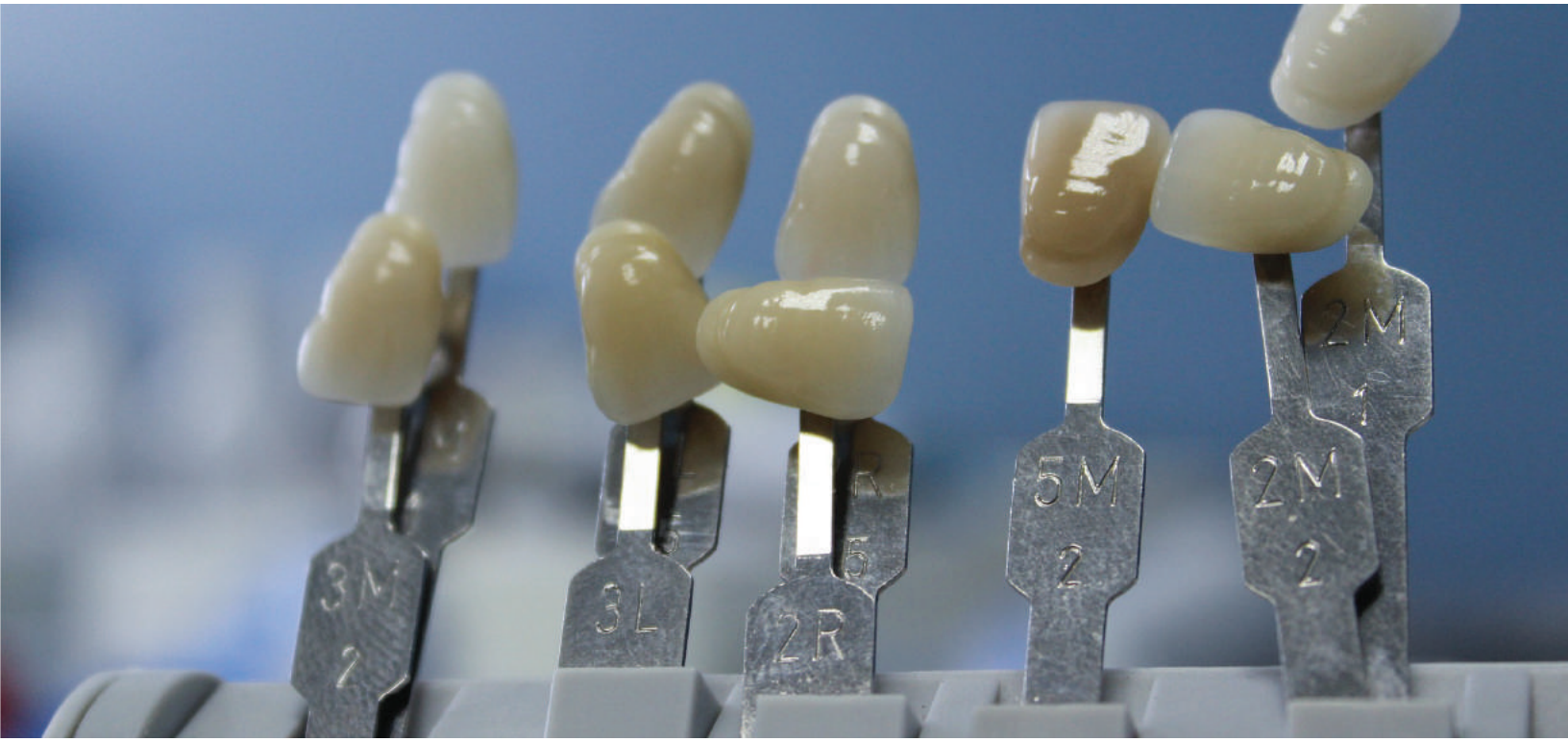

Conclusion

In conclusion, we have shown how the Nanovea Mechanical Tester, in Nanoindentation mode, provides precise measurement of the mechanical properties of a tooth. The data can be used in the development of fillings that will better match the mechanical characteristics of a real tooth. The positioning capability of the Nanovea Mechanical Tester allows full mapping of the hardness of the teeth across the various zones.

Using the same system, it is possible to test teeth material fracture toughness at higher loads up to 200N. A multi-cycle loading test can be used on more porous materials to evaluate the remaining level of elasticity. Using a flat cylindrical diamond tip can give yield strength information in each zone. In addition, with DMA "Dynamic Mechanical Analysis", the viscoelastic properties including loss and storage moduli can be evaluated.

The Nanovea nano module is ideal for these tests because it uses a unique feedback response to control precisely the load applied. Because of this, the nano module can also be used to do accurate nano scratch testing. The study of scratch and wear resistance of tooth material and filling materials adds to the overall usefulness of the Mechanical tester. Using a sharp 2-micron tip to quantitatively compare marring on filling materials will allow better prediction of the behavior in real applications. Multi-pass wear or direct rotative wear testing are also common tests providing important information on the long term viability.

To learn more about Nanovea Nanoindentation visit nanovea.com

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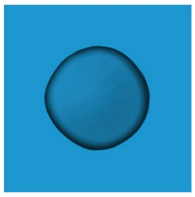
PB1000

MICRO  **AND**  **NANO**

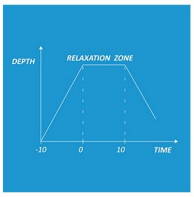
INDENTATION

FRACTURE TOUGHNESS

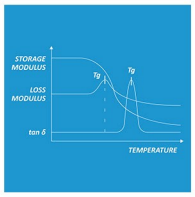
HARDNESS MAPPING



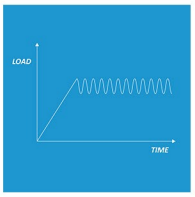
YIELD STRENGTH & FATIGUE



CREEP & RELAXATION



Tg GLASS TRANSITION



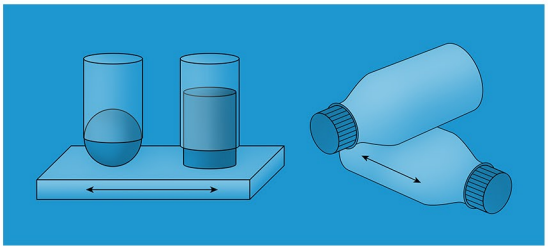
LOSS & STORAGE MODULUS

SCRATCH

COHESIVE & ADHESIVE FAILURE

SCRATCH HARDNESS

FRICTION



COEFFICIENT OF FRICTION

Fully Automated Nano Piezo Technology

The Most Advanced Mechanical Testers