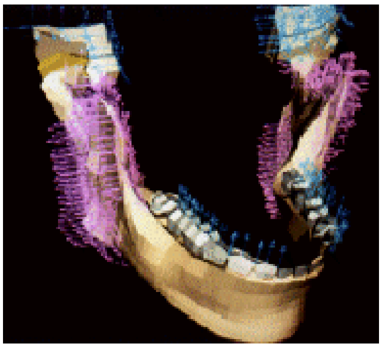
FATIGUE RESISTANCE OF A COMPOSITE POST

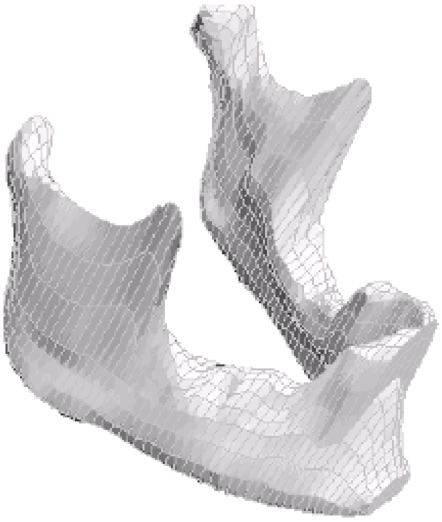
The objective of the following calculation is to determine the lifetime of a fiber reinforced composite post.

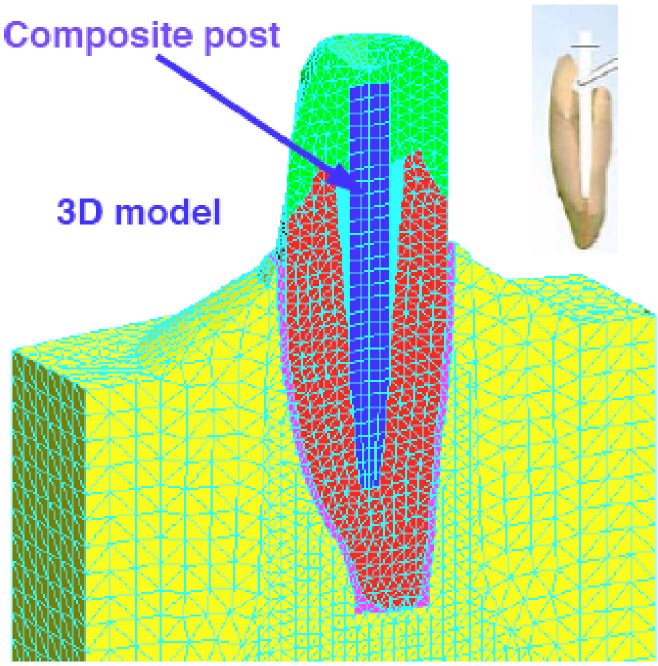
1. Modelisation of the tooth

Software : COSMOS/M of SRAC version 2.0.

From jaw to the simplified model :







2. Loading

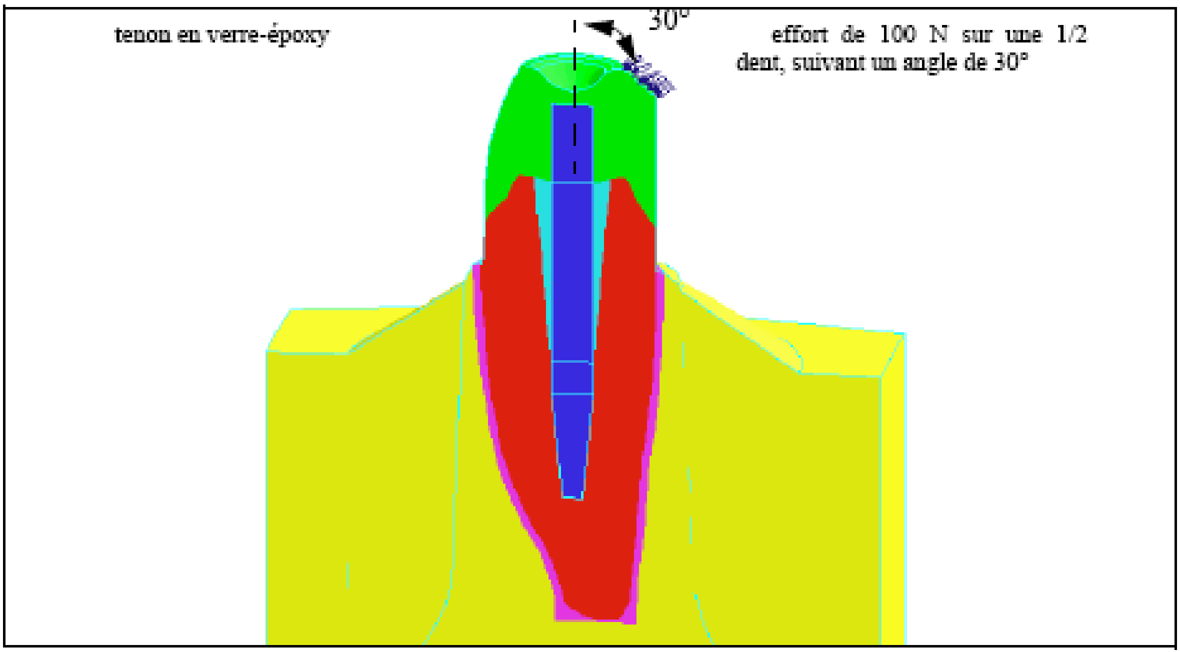
The loading charge and stress on a tooth during function vary from 100 N to 450 N.⁎ note 1

We shall consider a medium load of 200 N (20 Kgf) on the whole tooth doing a 30° angle with the longitudinal axis of the tooth and therefore of the post.

Figure 1

Case of a glass fiber/epoxy post

Loading of 100 N (10 Kgf) on half a tooth with a 30° angle

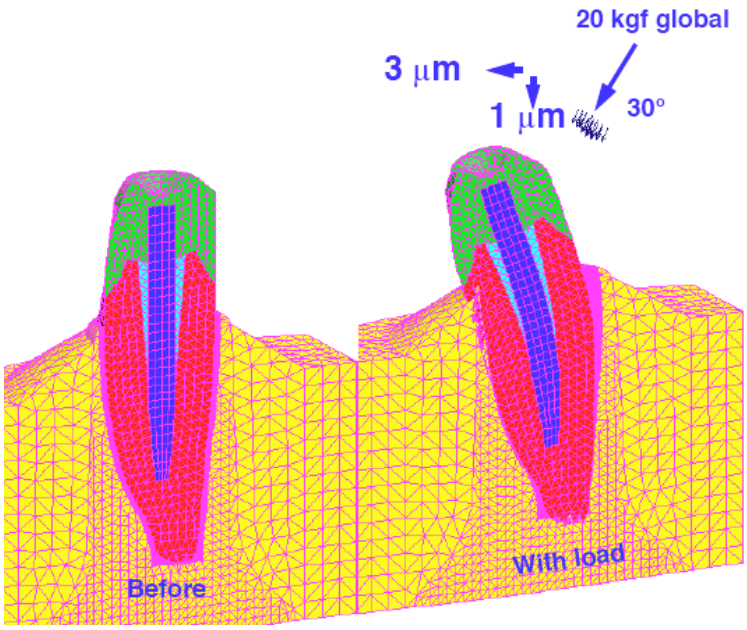


⁎ note 1 «Biomedical applications of polymer-composite material: a review» S. Ramakrishna, J. Mayer, E Wintermantel, Kam W. Leong Composites Science and Technology 61 (2001)

2. Calculation results

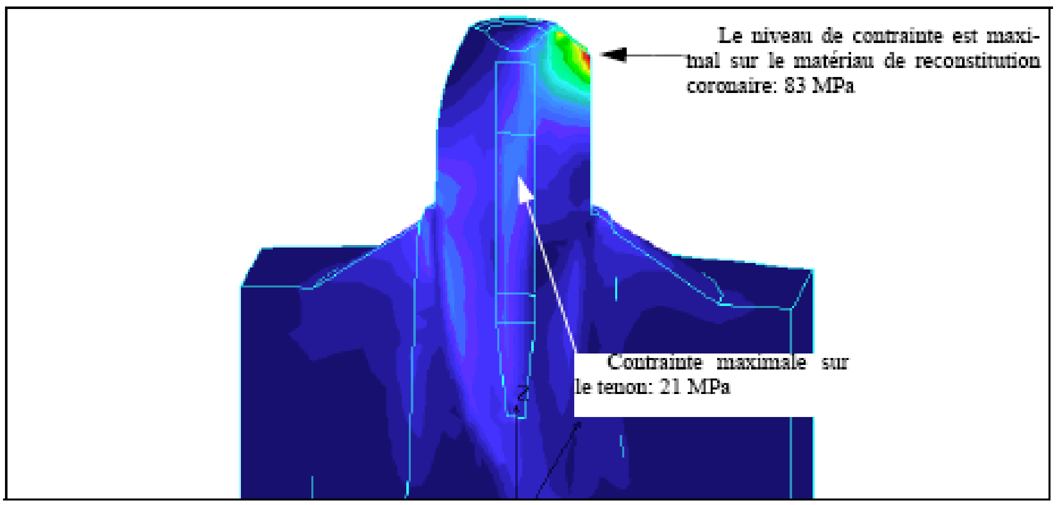
2.1 – Global post behavior

Figure 2 : the post behaves like a beam, with both flexural and compressive stress :



2.2 - Stress

Figure 3 : Von Mises stress



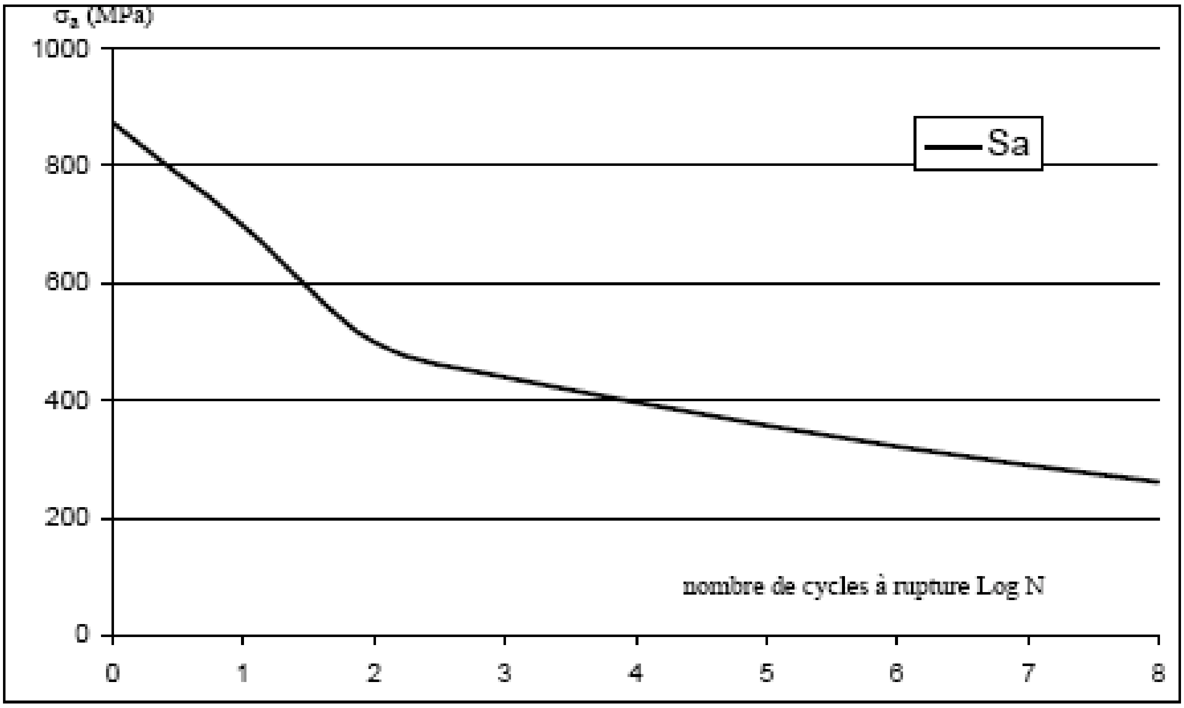
The stress level is maximal on the core composite : 83 Mpa.

On the post, the maximal stress level is 21 Mpa. The post is mostly sollicited in compression/flexion.

3. Results analyzis

Figure 4

Synthetic Wöhler chart for an unidirectional glass fiber reinforced composite with 60% fiber ratio in volume, in alterned traction/compression loading.



Above 10^8 cycles, the lifetime is said unlimited.

For an unidirectional glass fiber reinforced composite, the maximum load before breakage can be estimated up to 260 Mpa (i.e. 30 % * note 2 of the static resistance, 870 Mpa).

For a loading on the tooth of 200 N (20 Kgf), the calculation result gives a maximal stress on the post of 21 Mpa.
This is widely inferior to 260 Mpa with a margin of 260/21 = 12.4.
Therefore, the post is not concerned by fatigue.

The breakage in fatigue of a post in function could only be possible with an average load of 12.4 x 200 Mpa, i.e. 248 Kgf.

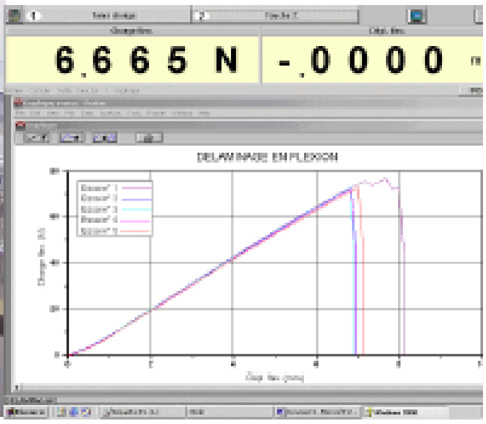
* note 2 «La fatigue des matériaux et des structures» Claude Bathias, Jean Paul Bailon Hermes

ANALYZIS OF THE MECHANICAL BEHAVIOUR OF ENDODONTIC

UNIDIRECTIONAL FIBER REINFORCED COMPOSITE POSTS

Before the calculation and modelisation for the finite elements analyzis study, tests have been done on UD composite posts by the CETIM of Nantes (TECHNICAL CENTER FOR MECHANICAL INDUSTRIES, www.cetim.fr).

For composites, mechanical tests are quite the same as the ones done for steel (isotropic material), but the results are more difficult to read because of the anisotropy : only specialists can read the results.



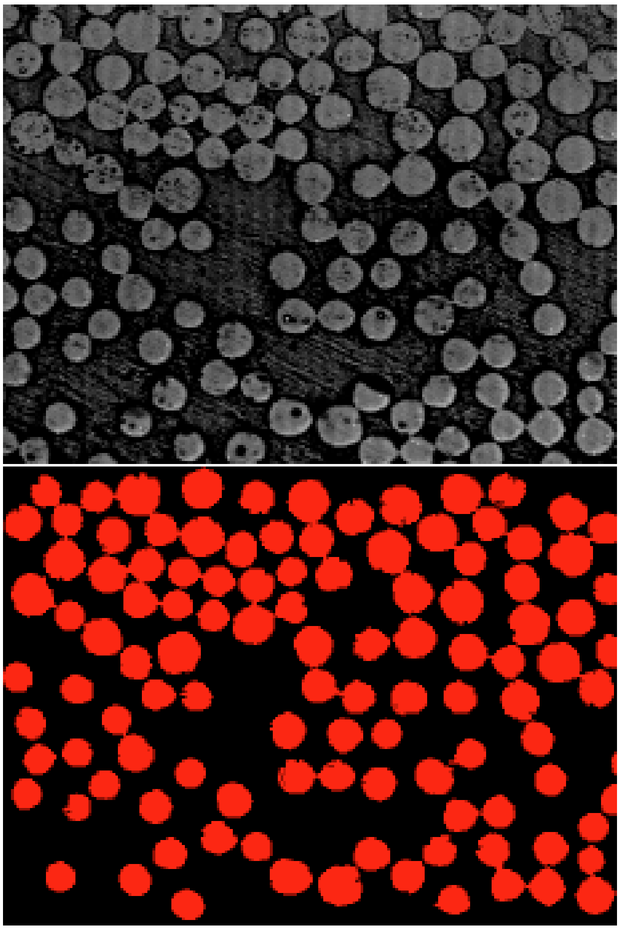
Examples of such results done for Carbotech

TEST	TENSILE STRENGTH	SHEAR STRENGTH	FLEXURAL STRENGTH
ISO	NF EN ISO 527 - 2	NF ISO 3597 - 4	NF ISO 3597 - 2
Carbon/epoxy post	114 200	40	1 540
Glass/epoxy post	42 500	30	920

MPa

About unidirectional fiber reinforced composite material :

• the resin has not a real mechanical importance,
• resin has to be chemically biocompatible.
• All the properties are linked to the fiber ratio.
• the axial properties of unidirectional composite material grows with fiber ratio, except in compression above 50% and except for transverse and shear limits.
•So, a too large fiber ratio must be avoided, fibers must have a good wetting by the resin matrix.
•Fiber choice begins from glass which is soft to carbon which can be stiffer than steel.

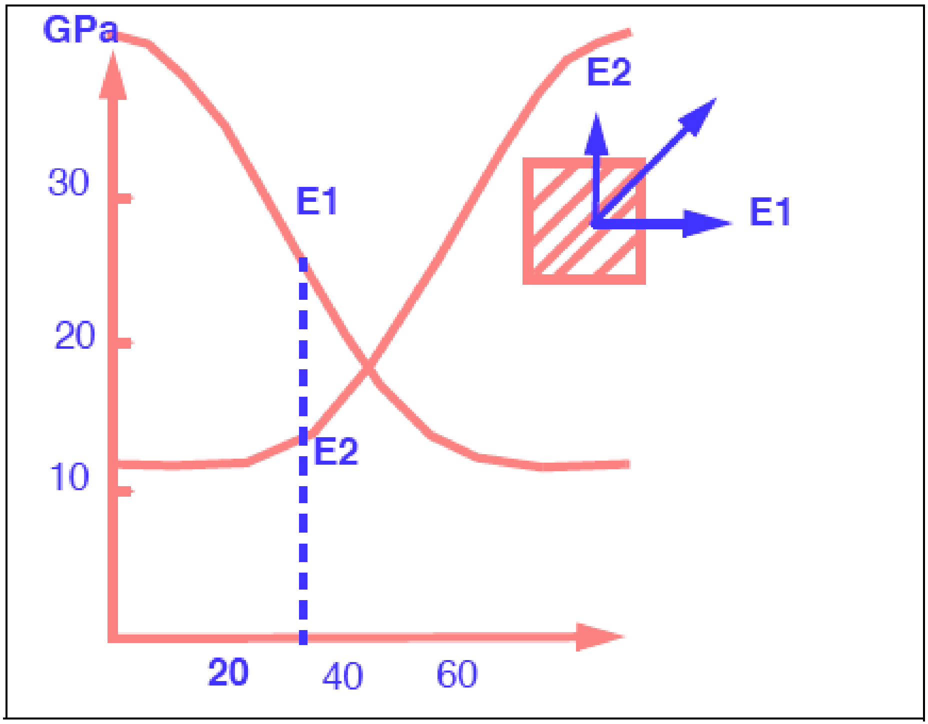


Comparing unidirectional fiber reinforced composite plate and beam mechanical behaviour :

• A plate is a mechanical pattern whose one dimension (thickness) is very low in comparaison with the two others (length and width).

• In the case of an unidirectional fiber reinforced composite plate, there are two elasticity modulus : the E1 longitudinal modulus, in the axial direction of fibers, the E2 transversal modulus, perpendicular to the fibers.

• so the variation of the elasticity modulus according to the angle of load application and with regard to the axis of the fibers is:



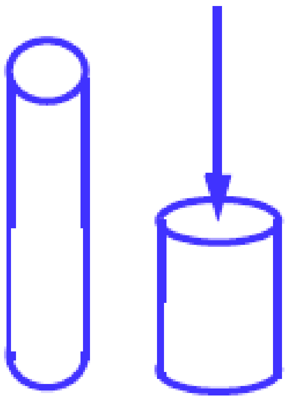
• a post is not a plate !

posts have a beam behavior :

• A beam is a mechanical pattern whose one dimension (length) is very higher than the section (in this case, the diameter).
• The composite post is a beam on a mechanical point of view and, in the case of a beam, only the axial Ex modulus is involved, no matter what angle of force is applied.

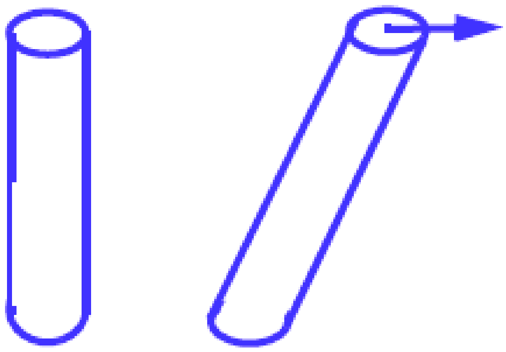
Corono-radicular posts are concerned by two types of stress :

Compressive stress



Shear stress

The angle changes



For unidirectional fiber reinforced composite,

• limit stress in the fiber direction is high, for exemple 1000 MPa

• limit stress in the fiber transverse direction is low, for exemple 50 MPa

• Shear limits are low, about 50 MPa

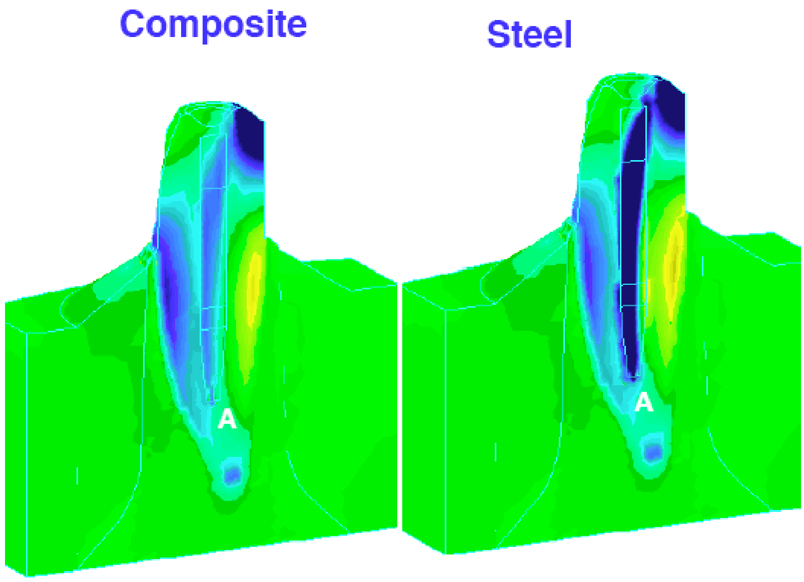
Comparing metal and unidirectional composite posts

Mechanically, a tooth behaves like a beam fixed at one end (a cantilever beam) :

the ideal root canal post must be elastic enough to accompany the flexural movement of the tooth, something that a very rigid post cannot do, it has to dilute the stress instead of concentrate them such as rigid posts do.

• A rigid post works against the natural function of the tooth. It creates zones of shear both in the dentine and at the interface post/core composite and post/adhesive cement whose elasticity modulus are very close to that of the dentine.
These tensions can cause cracks or fractures both in the tooth and core reconstitution.

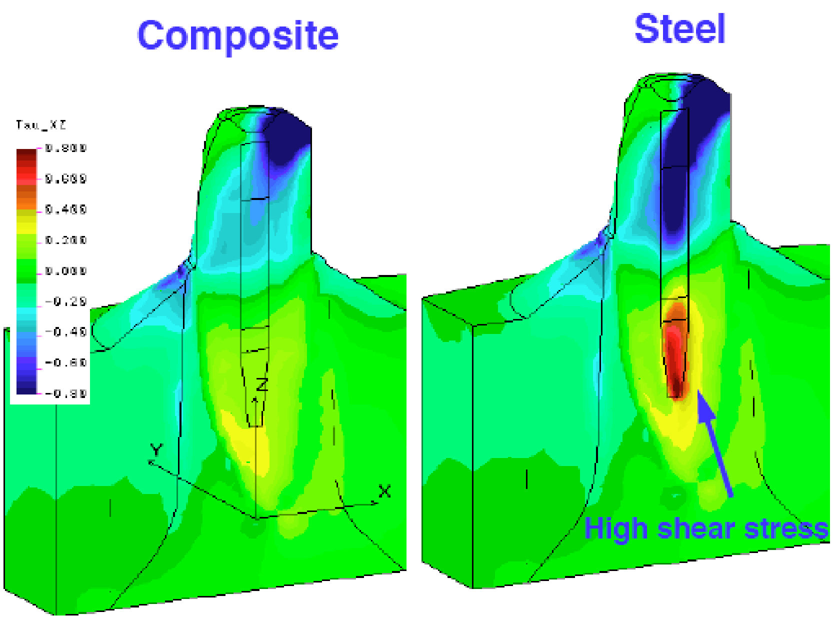
Behaviour of steel and composite post under compressive loading :



The steel post transmits hight stress to the dentine, especially in the root, point A.

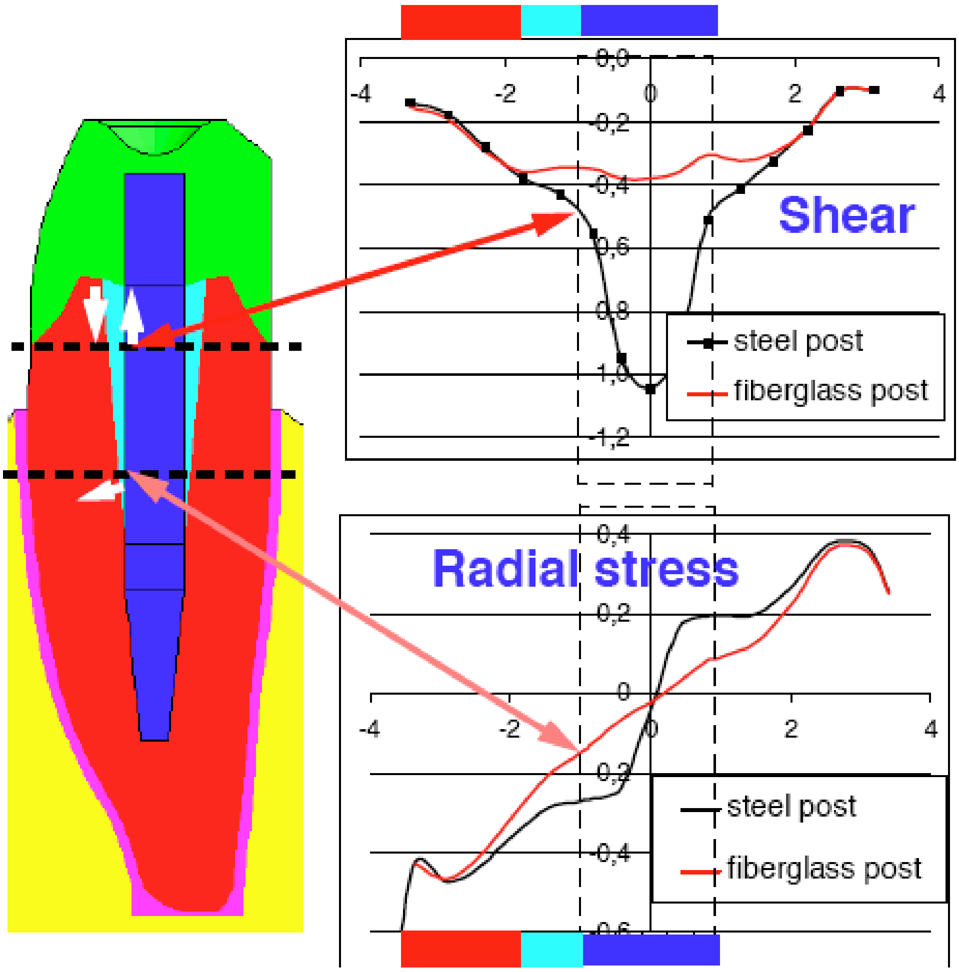
Because of the high stiffness of steel, stress is fully and immediatly transmitted to the root.

Behaviour of steel and composite post under shear stress :



• Composite post transmits well shear to all the coated surface : the adhesive cement used for sealing the composite post doesn't receive high stress.

Composite post diminishes shear stress by 50% !



Conclusion

On a mechanical point of view :
• stiffness is the fundamental data for dental posts,
• stiffness must be high enough in axial direction but lower in transverse direction to be adapted to the stiffness of the dentine
• UD composite post offers such adapted stiffness, thanks to its anisotropy, thanks to the fiber choice and ratio,
• stress developed is low , nor fatigue nor creep problems exist
• the adhesive cement and core composite are respected thanks to the shear stiffness and the low transversal modulus.