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Fig. 7 Strength dynamics of the two- and four-arm RPE

Fig. 8 Intercepts of the two- and four-arm RPE

32.9 N), maintaining far higher values as the activations progressed. Indeed, after 10 and 15 activations, the force remained over 250 N, reflecting the conserved high level of stiffness. However, any more than 15 activations were prevented by structural deformations causing a block in the activation mechanism. In contrast, the four-arm RPEs continue to express a fairly constant force even after 20 activations, albeit at a much lower level.

The statistical analysis confirms the above descriptive considerations. The mixed-effect growth curve model coefficient estimates are shown in Table 4. In particular, the t (t) statistically greater of two in absolute value indicates significant effects, and the coefficient table shows that:

- The linear term β is positive, indicating an initial positive growth. The cubic term γ is negative indicating that the increase in strength levels off as far as activation progresses. The cubic term δ is negative finally. All the three terms are statistically significant indicating a non-linear behaviors of activation vs. strength.
- Activation and type 4b interaction (β_{ab}) is negative and significant. This indicates that the initial increase is less steep for type 4b models.
- All the higher polynomial terms interaction are significant (γ_{ab}, δ_{ab}), indicating that the curvature for the growth dynamic of type 4b is different from that of the 2b models.

Figure 7 shows that a three-degree polynomial can well approximate the strength dynamics in the observed range. Growth curve model-specific intercepts (random effect) are shown in Table 5 and Fig. 8. A higher intercept indicates a higher starting level.

Post hoc means comparison analysis was carried on the repeated measures ANOVA used to confirm growth curve analysis results. Figure 9 displays graphically the results showing that 2b models consistently shows higher strength than 4b ones from activations greater than 2.

During the course of the experiments, no breakage or deformation of any of the bands associated with any of the RPEs tested occurred.

Discussion

As shown in Figs. 10, 11, 12, and 13, the bending moments generated by the RPE arms were analyzed on both the horizontal and vertical planes. The greater stiffness of the two-arm RPEs may be linked to their smaller size, which allows them to be positioned on the same axis as the crowns of the molars used for anchorage. On the horizontal plane, this permits a point of application of the force to pass through the center of resistance of the system (which is determined by the expander as a whole, welded to the orthodontic bands), namely the anchoring

Table 5 Model-specific intercept

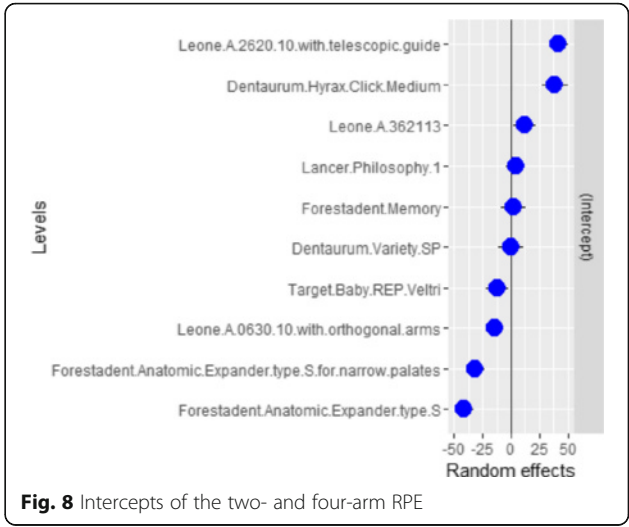|	(Intercept)
Dentaurum.Hyrax.Click.Medium	37
Dentaurum.Variety.SP	1.1
Forestadent.Anatomic.Expander.type.S	−39
Forestadent.Anatomic.Expander.type.S.for.narrow.palates	−31
Forestadent.Memory	0.27
Lancer.Philosophy.1	5.4
Leone.A.0630.10.with.orthogonal.arms	−16
Leone.A.2620.10.with.telescopic.guide	44
Leone.A.362113	13
Target.Baby.REP.Veltri	−14