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"Restomodding" Wall-Hanger Guitars

by Roger Häggström

CHEAP GUITARS were made in great numbers all over the world at the beginning of the last century. In Sweden, the driving force behind a burgeoning interest in guitars was the independent church movement. The prevailing sentiment was that every able-bodied parishioner should be able to play three chords on a guitar at prayer meetings and fundraisers (**Photo 1**). Many of these instruments still exist, mostly in unplayable condition. I have found ways to restore these wonderful old guitars and make them play and sound better than ever.

I love the bass-balanced sound of old-style ladder bracing in a small steel-strung parlor guitar. The complex sounds keep me wanting to play another chord. Modern X bracing gives more bass but also less varied tone, in my opinion.

I do restorations and modifications ("restomods") of wall-hanger guitars for a living. Preserving the original patina and the history of the instrument is important, but enhancing tone, durability, and functionality is always my number-one priority. I've done about 190 of these "GammelGura" (that's "OldGuitar" in Swedish) restomods so far.

My ideas and methods have been developed over many years of empirical experimenting where I compare the sound before and after changing a detail in one guitar. To avoid being misled by the psychoacoustic effect, I try to be objective and not to expect anything. Successful ideas are then implemented on succeeding guitars to validate the findings. Without scientific hard data, and while acknowledging the danger that I may only be hearing what I believe, I will describe how I came to my conclusions.

I work with old, plain, factory-made guitars in bad shape (**Photos 2, 3, and 4**). Despite their low collector value, they have great potential, being handmade with aged and solid old-growth woods. They were made to be easily repaired, built with hot hide glue and shellac-based varnish. Correcting the mistakes and cheap mass-production design features of these guitars will improve the sound and playability immensely. Giving new life to old guitars like this also gives me ample opportunity to try out and develop new ideas.

The ladder bracing in old and inexpensive guitars was usually very simple, with just three transverse braces across the top: one (or sometimes two parallel braces) above the soundhole, and two (or sometimes only one) below (**Photo 5**). Not much effort was put into the bracing pattern, although some variations on this basic formula can be found. Sometimes the two braces below the soundhole were slanted. The main third brace could be placed above or just below the bridge on top. Sometimes there were thin spruce patches on either side of the soundhole designed to reinforce that weak area. The bridge plate could be large or small, or omitted entirely.

Parlor guitars before the 1920s were often dimensioned for gut strings with low tension compared to modern-day steel strings. The neck was often thin or made of soft woods, like the poplar used in old Levin guitars. The braces in European parlor guitars were typically too thick, too tall, and made of flat-sawn wood. Parlors made in the USA typically had braces with smaller and more suitable dimensions, but sometimes the tops themselves were excessively thin.

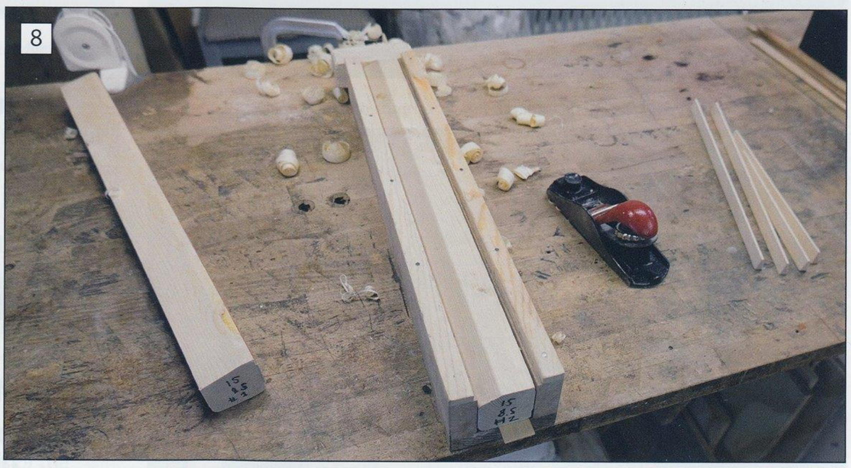
COURTESY OF ROGER HÄGGSTRÖM

ALL BY ROGER HÄGGSTRÖM EXCEPT AS NOTED

***Photos 2, 3, and 4.** A typical guitar wreck. This one is a very basic tailpiece Levin from 1914. The name "Edvin" is scratched into the soundboard. **Photo 1** shows the original owners. Is that you, Edvin?*

Studying old guitars is a great way to learn the effects of aging on the construction and integrity of the instrument. Wood shrinks, loses weight, and becomes brittle with age. Almost all old guitar tops have cracks on either or both sides of the fretboard. These cracks typically result from the rotation of the neck into the soundhole caused by the tension of the strings, and from the wood in the fretboard shrinking more than the top. Cracks also typically occur in front of or below the bridge as a result of top wood shrinkage and/or the rotation force from the pin bridge. The hardwood in the back shrinks across the grain, and it's not uncommon to find cracks in the middle joint of the back (**Photo 6**) or too-tightly fitted back braces pushing out the sides of the guitar.

Ladder bracing is nowhere near as strong as X bracing. When guitars became bigger in the 1930s, some factories added more ladder braces or made the braces bigger to make the top stronger. It never really worked; the guitars were just over braced. Big guitar tops need the strength of X bracing. But for a parlor-size guitar, I think that ladder bracing is the best alternative. The small top makes ladder bracing strong enough for a standard 0.011 steel string set, and you also get the great sound from a ladder bracing.



I'll spend a couple of hours taking the guitar apart so that I can have total access to the guts of the instrument. If the top and/or back are too thick, they will be thinned from the inside. I will replace all the braces on the top and the back (**Photos 7, 8, and 9**), although I sometimes keep a couple of the original back braces, readily visible through the soundhole, for aesthetic reasons. The combination of fresh, tough wood in the bracing, and old and brittle wood in the rest of the guitar is great for both the durability and the sound.

When I add new parts inside the guitar, I don't like to make them look old artificially. With time, they will blend in nicely with the old wood. Until then, they will proudly show the recent history of the guitar.

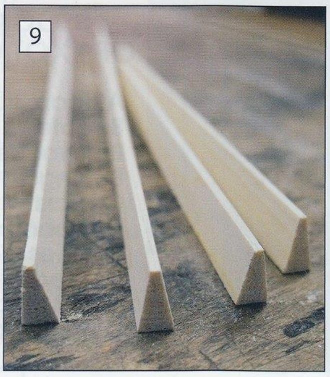


Photo 5*. The disassembled guitar. The neck is soft poplar, the back and sides birch, the fretboard walnut. In all their old parlor guitars, Levin uses a tone-killing birch torsion stick under the saddle. That gives fewer cracks in the top but only the sound of the strings.*
Photo 6*. The back had two missing braces and two loose braces. The bookmatched back had a knot covered with a spruce cleat. It was called "tone cushions" if the customer asked about it!*
Photo 7*. Shaping the radius of the braces with the LMI jig, 20" for the bottom and 30" for the top braces. This is done before triangulating.*
Photo 8*. The jig to triangulate braces from 8mm ×15mm brace blanks. Two loose inserts gives the angle for the plane. The box is movable so I can change direction of the planing if the wood has a bad runout. Thin shims of different thicknesses are used under the inserts to match the actual blank size to the jig.*
Photo 9*. Tapered braces.*

When doing repairs and adding new parts, I use protein glues like hot hide glue or fish glue whenever possible. These are the same glues that were used when the guitar was made.

The new braces in the top are glued when the sides are already in place. That makes the gluing of the braces a bit harder, but not a problem with a go-bar deck.

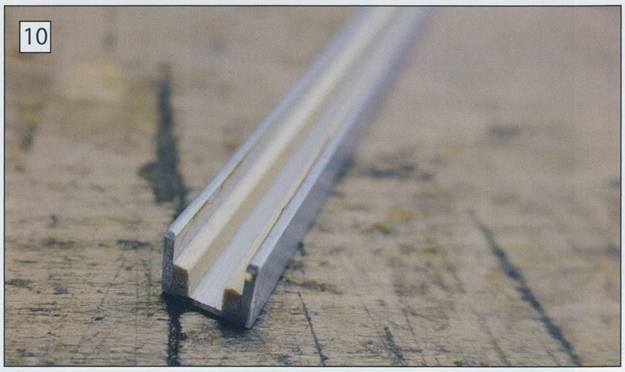


Photo 10. My special caul to glue the tapered braces is made of a U-shaped aluminum channel with small sticks of soft basswood glued inside.
Photo 11. The back braces are glued using the special caul on top and a 20″ radiused caul under the back. The red light comes from a heat lamp to give the hot hide glue longer set time.
Photo 12. The new braces glued to the back and shaped. When the back is shrunken, you need to add new wood to fit the outline. On this one I put a rosewood strip between the two halves of the back. I usually make the third brace flat to make the back more flexible, but this back was thin and needed more stiffness.

To prevent top cracks along the fretboard, and to support the weak spot around the soundhole, I use a thick and strong upper brace and an A-frame reinforcement (**Photo 13**). The A-frame, used in some newer Martin models, is surprisingly strong even with thin 6mm×6mm (0.24″×0.24″) spruce braces. More recently I have added a thin 2mm (0.08″) cross-grain spruce patch to the plan. In my opinion, the upper part of the top doesn't add much to the sound of the guitar, so it can and should be made very sturdy.

The main brace under the fretboard keeps the rectangular cross section from the brace blank for added strength. The other two main braces are shaped to a triangular cross section with a rounded top edge. The main braces are all made from 8mm (0.32″)×15mm (0.59″) blanks, and their maximum finished height is about 12mm (0.5″). If the guitar is bigger, I will make the main braces a bit higher. I use old-growth quartersawn Swedish European spruce in the top braces.

The brace directly below the soundhole must be strong enough to reinforce the weak area around the soundhole, but it must not be too stiff, as it is close to the main sound-producing part of the top around the bridge.

The main brace in front of the bridge is the most important tone brace. It should be as light and stiff as possible, but still strong enough to keep the top in shape. I select the lightest and stiffest spruce I can find for this brace.

Between the 2nd and 3rd braces, below the soundhole and toward the center of the top, I place a thin spruce patch about 1.5mm (0.06″) thick along the grain for added strength (**Photo 14**). I like to give the top a sort of reinforced backbone under the strings. Below the bridge, I add a thin spruce stick, mainly to keep the fibers in the top together. My experiments

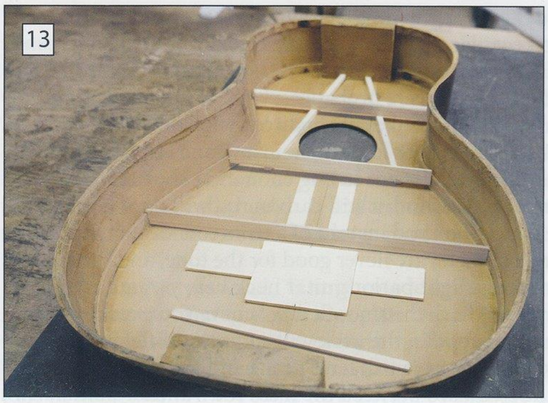


Photo 13. *All the rough braces for the "Edvin" parlor guitar laid in position.*

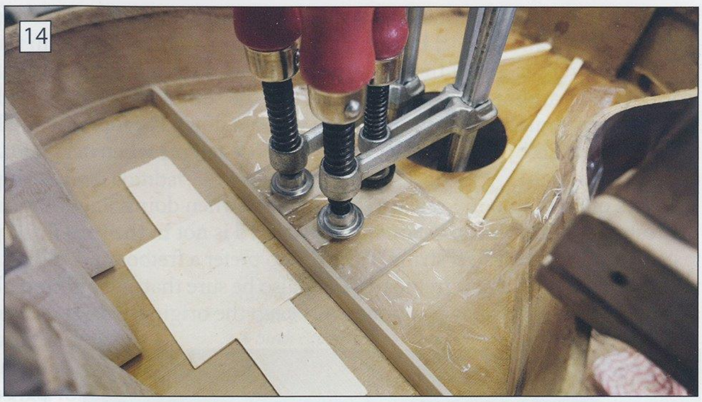


Photo 14. *Gluing reinforcing spruce patches in the top. Now I just make one triangular patch, so as not to induce stress points along the grain where a crack might start.*

Photo 15. *Gluing the pieces of the spruce cross-shaped bridge plate together with hot hide glue.*

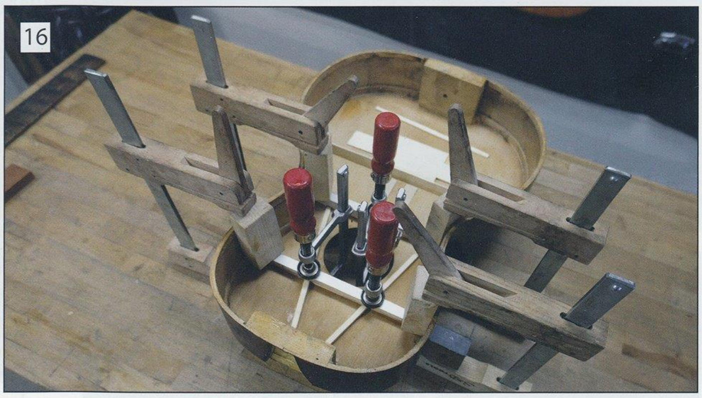


Photo 16. *The last gluing of the two top braces. Channels and notches for the A-frame braces are cut into both. This is how I did it a year ago; now I always use a go-bar for the top and a reinforcing patch under the A-frame.*

have shown that small amounts of glued-on lightweight spruce can strengthen the top in strategic places with little, if any, discernible negative effect on the tone.

The bridge plate is where I do something different. I make it cross-shaped with three glued-together pieces of spruce (**Photo 15**). To counteract the rotation of the bridge, the middle part of the bridge plate has grain running parallel to the grain in the top. The grain of the wings of the bridge plate goes across the grain of the top. The wings extend beyond the ends of the bridge above to prevent cracks forming at those stress points. The bridge plate is about 3MM–4MM (about ⅛″) thick in the middle and thinned down to nothing towards the ends of the wings and the lower end of the middle part. The middle part has roughly the cross section of an airplane wing.

All the main braces have thinned-down ends (**Photo 17**). The slope of the ends begins about 60MM–70MM (2.4″–2.8″) away from the sides, and at the junction, with the sides the brace is about 1MM (0.04″) high. The tips of the main braces are tucked into a small gap made under the lining. The gaps made for the original braces are filled in with sawdust and glue.

All the bracing in the top, including the bridge plate and patches, is given a shallow 30′ radius. The top should not be perfectly flat, but rather have a gentle arch in both directions. The tone will be more focused and the top will not crack as easily with a slightly domed top.

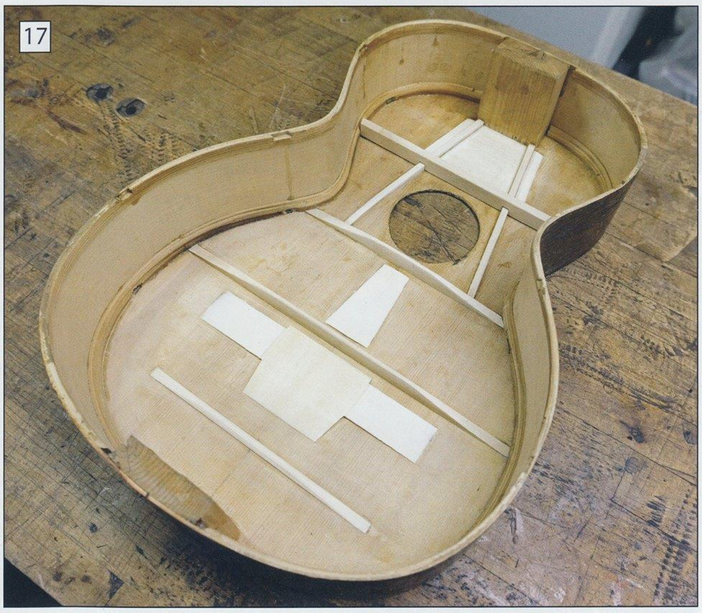


Photo 17. *Top braces shaped in a recent ladder bracing with the reinforcement patch under the A-frame, a single patch in the middle, and brace ends tucked in under the lining. The sides of patches in a top should always be thinned out to nothing, or cross more than one grain in the top, to prevent cracks from forming. The main brace under the fretboard is not yet glued.*

When doing the final shaping of the braces and before gluing the back and bridge, I tap in the bridge area and listen to the resulting sustain. If the sustain is too short, I shave more from the ends and/or top of the braces below the soundhole. I also use my thumbs on the bridge area to press down the top to feel how flexible the top is. I let my experience tell me when enough is enough.

More often than not, I replace the fretboard when doing the restomod. The typical original flat fretboard is not in the taste of most modern steel string players, who prefer a fretboard with a radius. With a new fretboard, I can also be sure that all the frets are accurately positioned. If I keep the original fretboard, I typically fill in the original fret cuts and resaw them in the correct places (**Photos 18, 19, and 20**). I have often seen original fret placements that are pretty good until the 12th fret, but the higher frets were probably set by eye and are way off.

The new bracing makes the body of the guitar strong enough for 0.011 steel strings or low-tension Newtone Heritage 0.012 strings, but the neck is not strong enough. A short 12-fret neck doesn't need a truss rod; a stiff carbon rod will do.

I prefer a carbon rod instead of a truss rod for many reasons. Big chunks of metal are never good for the tone, and the added weight makes a light parlor guitar neck heavy. A truss rod never gives the neck the smooth relief curve you expect when adjusting; the wood in the neck will compress differently along the neck and the curve will have peaks and valleys. Only the part of the fretboard between the truss rod's anchor points will actually bend. Some types of truss rod, when adjusted, will lessen the compression in the plane of the frets in the fretboard, making the neck less stiff. The milled slot in the neck makes the whole neck weaker, especially at the weakest spot near the nut if the truss rod nut is at the head, or from the neck joint to the body if the truss-rod nut is at the other end.

Carbon rods, on the other hand, are strong and firmly glued in place and have about the same weight as the removed wood in the neck. The carbon rod does not creep and bend from tension with time, as wood or a metal reinforcement is prone to doing. I always put a carbon rod in the neck, which is easy with the fretboard off. Even if the neck is hard and thick, the carbon rod doesn't hurt. I use epoxy to glue the carbon rod into the neck, and a thin wood strip to cap the rod so I can glue the fretboard with hot hide glue.

With a stiff neck, it's much easier to reset the neck at the correct angle with strings at tension. A stiff neck is also good for volume, attack, and clarity. I sand a nice smooth 0.1MM–0.15MM (0.004″–0.006″) relief in the fretboard and frets with the neck in the shape it has with strings at tension. Then I trust the carbon rod to keep the shape of the neck in place.

I use a hollow square carbon tube because it's lighter and retains most of the stiffness of a solid rod. The tube is 10MM (0.4″) with an 8MM (0.32″) hole. I fill the hole in the carbon square with a matching round birch rod and a short piece of solid carbon rod at the heel end. Old parlor guitars often have a weak and cracked heel. To reinforce or repair the heel, an 8MM (0.32″) hole is drilled almost through the height of the heel and filled with a birch rod glued with epoxy. I drill the hole through the solid end of the square carbon tube to constitute a very strong L-shaped reinforcement (**Photos 21–24**).

The guitar's sound is as important as its structural strength. All the energy driving the guitar comes from strumming or picking the strings. The composite of the frequencies, the sound "recipe" generated by the strings, is filtered, or attenuated, at every possible intersection of the various materials that constitute the guitar. Guiseppe Cuzzoli and Mario Garrone describe this process in their book, *Classical Guitar Design*. Some energy from the strings is lost to internal friction and heat, some frequencies will readily pass through the filters, and other frequencies are attenuated or reflected back. Frequencies filtered out before they arrive at the main sound-producing parts of the guitar, the top and back, will be more or less lost. For example, a solid bone saddle seems to increase trebles, but what it actually does is not attenuate the trebles as much as a plastic saddle. With this simple dynamic in mind, I believe that the parts of the guitar closest to the strings (the nut, saddle, bridge, and bridge plate) are most important for the shaping of

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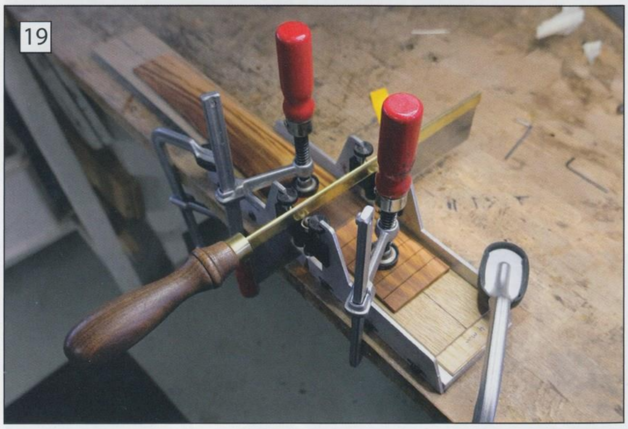

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Photo 18*. Marking the fret positions using a nice large caliper. I mark with a sharp awl for better precision. When sawing the fret slot, I make sure that the dent from the awl is visible on both sides of the saw.*
Photo 19*. Sawing fret slots with an early StewMac fret-slotting miter box.*
Photo 20*. Instead of using the cumbersome adjustable screws in the miter box, I have made a selection of plates of different thicknesses to put under the fretboard to set the perfect saw depth.*

the tone. I have not experimented with string pins. On old parlor guitars, ebony pins with 4MM (0.16″) pearl dots are pretty much mandatory.

Historically, a bridge plate was not really required for a gut-strung guitar. Gut string knots rarely damage the soft spruce around the bridge-pin holes. But the ball ends of steel strings require reinforcement on the soundboard, typically in the form of a hardwood plate. Over time, this hardwood plate grew to become an integral structural part of the top, equally designed to help combat the rotation force of the bridge. It strikes me that few builders gave much thought to the adverse effects of a large hardwood bridge plate on the tone of the guitar.

I once came across an old Finnish-made instrument with nothing but spruce on the top. The spruce bridge plate was a bit worn, but it was easily repaired, and I was able to keep everything original as the customer wanted. To my surprise, I could hear an unusually beautiful, warm, open, and complex tone in this guitar. At the same time I realized that the oversized torsion bridge plate in old Levin parlors, in the form of a 30MM (1.18″) wide and 3MM (0.12″)

Photo 21*. The milling jig to cut the channel in the neck for the carbon rod. The neck is secured with two small screws on either side of the cut on top and a caul under the neck secured with wedges. Note the tuner post plugs: The holes for the tuner posts need to be redrilled to the modern standard spread for the replacement tuners. European tuners before 1950 had a varied and tighter spread between the posts.*

Photo 22*. The square carbon tube and other parts that will be glued into the neck.*

Photo 23*. I made a test gluing a piece of solid 8MM carbon rod into the hole in the carbon tube and drilled a hole for the 8MM birch rod I use to strengthen the heel. The L shape turned out to be very strong!*

Photo 24*. The square carbon tube glued in place in the neck. A birch cap on top of the tube and a birch rod (and now also a piece of a solid carbon rod) inside the tube is added.*

Photos 25 and 26*. Gluing the fretboard using two nails as alignment pins. Basswood sticks of different thickness are used to add pressure to the sides of the radiused fretboard.*

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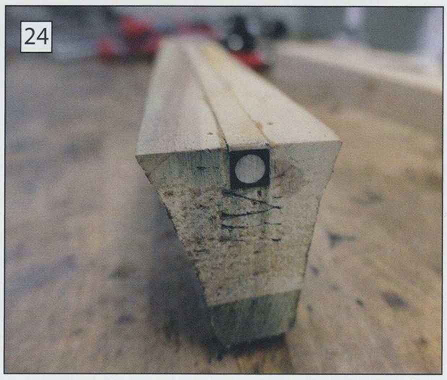

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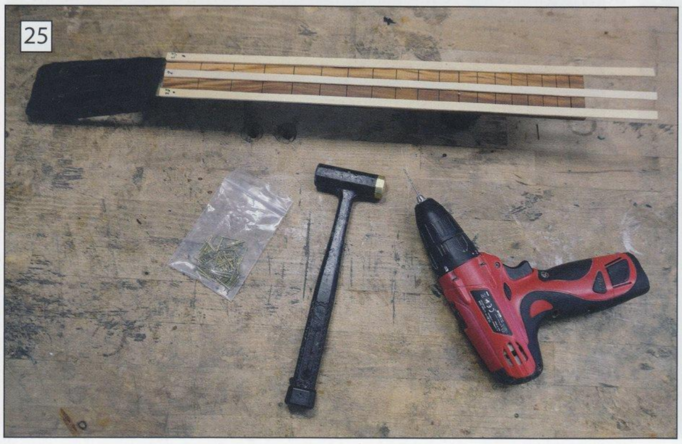

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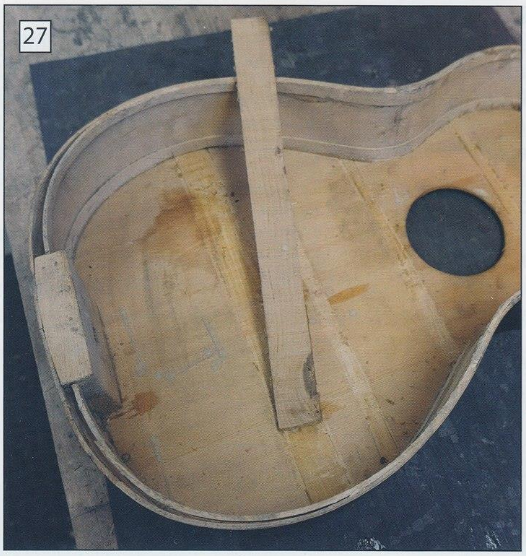
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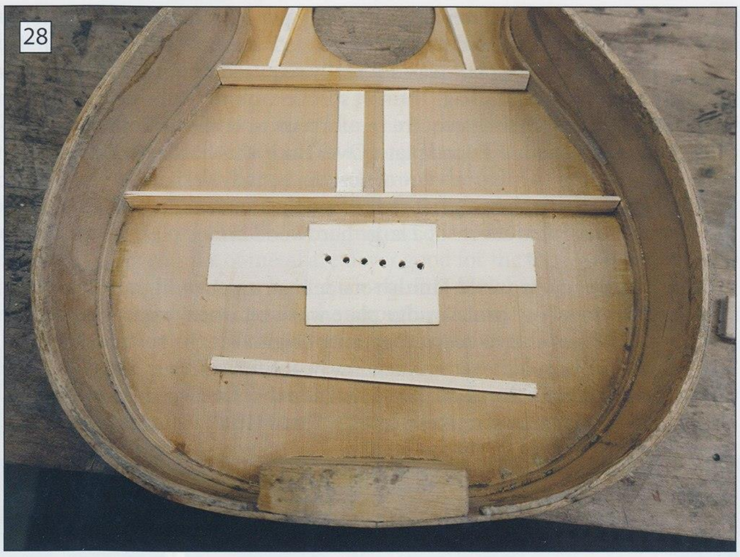
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thick birch strip across the whole top, is a real tone killer (**Photo 27**). Maybe using hardwood in the top bracing isn't the best idea. In my next restomod, I used a spruce bridge plate with harder maple buttons inlaid around the string-pin holes with a StewMac BridgeSaver. This achieved the same beautiful tone as in the Finnish guitar. After that, I have never used any wood other than spruce in bridge plates.

Since then, I have replaced the maple buttons in my bridge plates with much harder bubinga wood. There are many other really hard woods that could be used. Maple is actually a bit too soft to cope with the wear and tear from the ball ends of steel strings. I think that these individual, separated wood buttons also contribute to the separation of the sound from the individual strings.

More recently, I have also seen spruce bridge plates extending about half the width of the top in USA-made parlor guitars from the 1890s, so this idea is not a new one. But with no reinforcement around the bridge-pin holes, all those old spruce bridge plates were badly chewed up.

One plausible explanation for this improvement of tone is that hardwood in the bridge plate may attenuate some of the most important frequencies for the spruce top, and, at the same time, let pass some frequencies that the spruce top in turn will attenuate.

The original plain-spruce-rectangle bridge plate I started with gradually evolved into the three-piece cross-shaped bridge plate that I use now (**Photo 28**). The central part, with its grain oriented in the same direction as that of the top, is stiff and can be made long or short, depending on the relative strength needed to counteract the rotation of the bridge.

I intonate each string individually at both the saddle and nut. Even a perfectly placed slanted bridge saddle will typically have to be thick on a short-scale parlor guitar, around 4MM (0.16″), to reach all the intonation points. This makes a solid bone saddle heavy. To make it lighter, I installed separate bone posts, 5MM (0.2″) wide, one under each string, and filled the voids between the posts with light spruce. I glued the bone and spruce together to constitute a one-piece segmented saddle. This is practical, requiring no additional change to the construction of the bridge.

When trying out my first segmented saddle, it took some time to sort out exactly what I was hearing. The sound was very different from the sound of a solid bone saddle. The difference in the weight of the saddle alone could not fully explain it. I discerned better string separation from the segmented saddle. When playing a chord, I could hear that the individual strings of the chord did not blur into a uniform sound as much as with a thick, solid-bone saddle. I also noticed that the headroom increased; the guitar kept on sounding good and providing more volume, even when strummed quite hard. Also, the sound became more dynamic and not as compressed as with a solid-bone saddle. On the negative side, there was a noticeable loss of volume and a less aggressive attack. But the biggest surprise was that the tone changed for the better with the segmented saddle. I concluded that the reason for this must be the spruce mated to the saddle bone.

I made a batch of segmented saddles, with different woods between the bone posts, and tried them out on the same guitar. All hardwoods sounded about the same and not as good as the softer woods. The only wood I tried that could compete with spruce was cedar, another soft wood commonly used for guitar tops. The cedar saddle gave the guitar a different and darker tone than the one with spruce. My theory for these changes of tone is that the wood in the segmented saddle changes the filtering properties of the full frequency recipe coming from the strings.

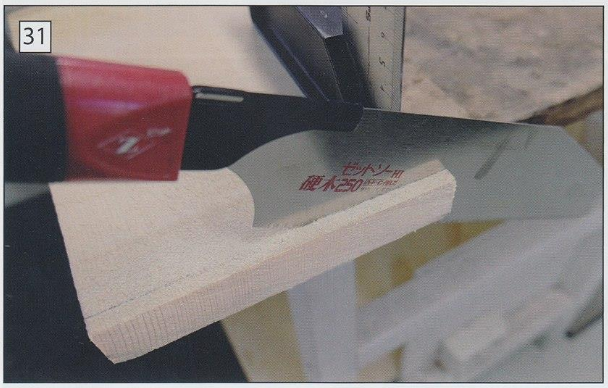
After listening closely, and comparing the spruce and cedar segmented saddle on the same spruce-top guitar, I concluded that the spruce segmented saddle enhanced the "sound of spruce" with extra everything, and that the cedar one sounded good but a bit mismatched to the top with lower overall volume.

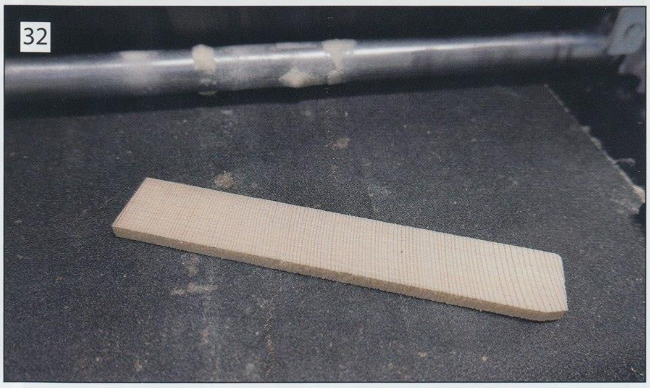
I also tried stand-alone bone posts with no wood in between. I achieved the same string separation and increased headroom but no tonal change, as I had with saddles with wood connecting the bone posts.

An Internet search revealed that there had indeed been attempts to cut solid-bone saddles into separate pieces, primarily as an expedient to solve the problem of uneven volume from UST pickups. Eltjo Hasselhoff addressed this challenge some ten years ago, reporting that the segmented saddle also improved the acoustic unamplified sound of the guitar. The use of wood between separate bone posts in a saddle is an innovation, as far as I can tell.

I construct the segmented saddle from a single piece of spruce, cutting notches for the bone posts (**Photos 29–32**). I impregnate the spruce in between the posts with thin superglue. The glue strengthens the wood, and also acts like a sort of lacquer. I cannot discern any major difference in tone between saddles with or without this superglue reinforcement. I custom build a segmented saddle for each individual guitar, since the string spread, thickness, length, height, and crown of the saddle are never uniform between one old guitar and another.

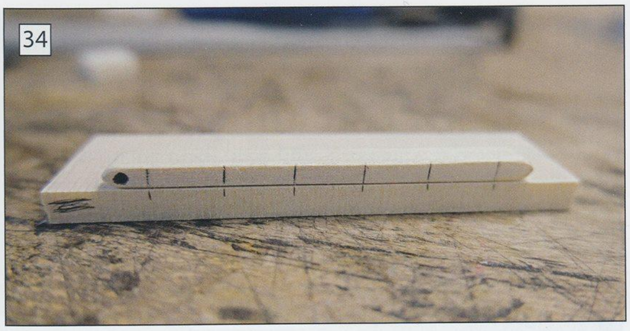
The segmented saddle is as strong as a solid bone saddle when tightly fitted in the saddle slot, but care must be taken when removing it from the slot since the spruce is brittle. To make the saddle stronger, I superglue a thin piece of wood (the same wood as the bridge) on the underside of the finished segmented saddle to safely hold the parts together. This also gives me another chance to adjust the final height of the saddle.





Photos 29 and 30. *I use a slightly modified Proxxon KG 50 grinder to cut the bone posts from camel-bone blanks. The blanks are precisely thinned down in my drum sander to around 5MM thickness to match various size cuts in the spruce blank for the segmented saddle. I cut the bone posts to about 5.5MM length to match the thickness of the spruce blank.*

Photos 31 and 32. *A piece of spruce with vertical grain is cut for the segmented saddle and sanded to the 5.5MM thickness of the precut bone posts.*



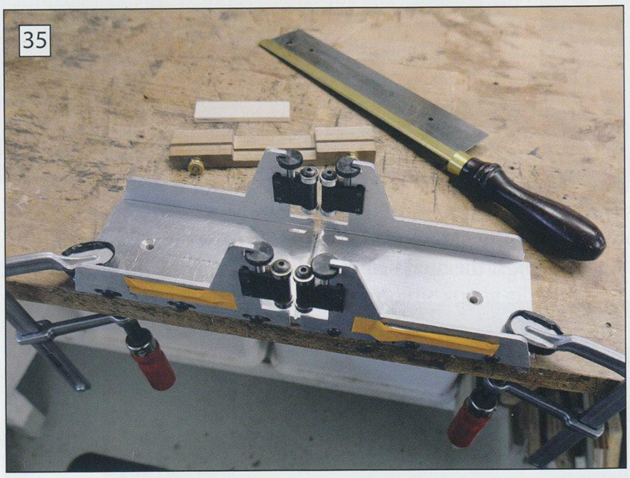
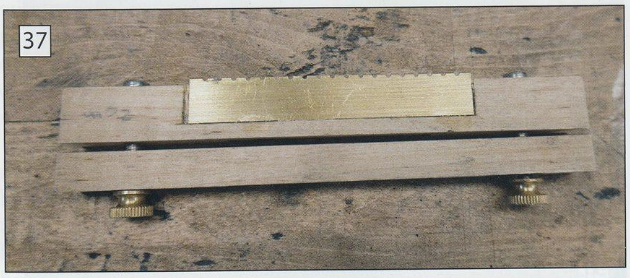
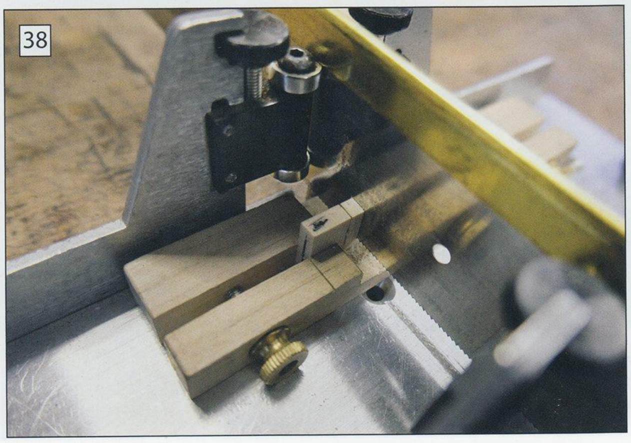
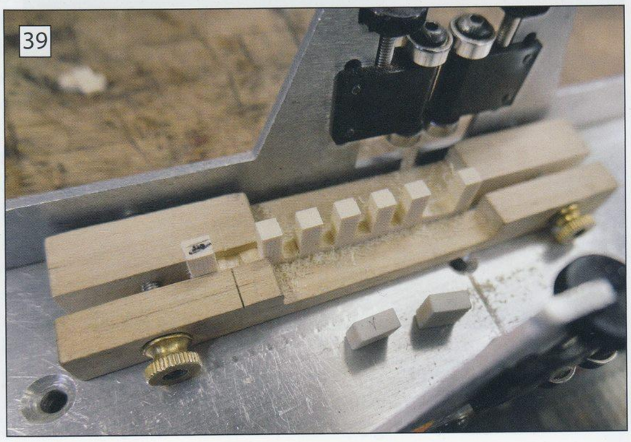
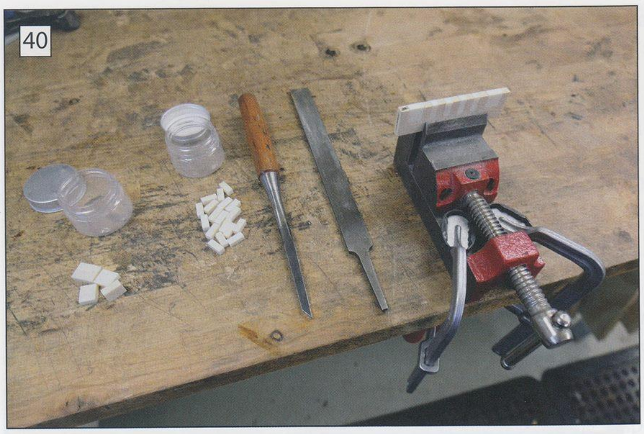


Photo 33. *A temporary spruce saddle is fitted to the saddle slot and marked with the exact position of the strings, using a long ruler from the notch in the nut to the center of the string pin hole. The bass side is marked with a black dot.*
Photo 34. *The markings are transferred to the piece of spruce prepared for the segmented saddle. I make sure to mark the bass end, too!*
Photo 35. *I use my StewMac miter box and a special jig to cut parallel and straight slots 5MM wide in the piece of spruce.*
Photos 36 and 37. *The brass plate in the jig has been notched to 5MM by CNC.*
Photos 38 and 39. *The outermost bone posts are made wider to fill the length of the saddle slot.*
Photo 40. *The precut bone posts are fitted to the cuts in the piece of spruce using a 5MM thick metal file and a 4MM chisel.*
Photos 41 and 42. *The bone posts are glued with StewMac's tough number 30 superglue. I use an extractor for the fumes and a gas mask when doing this gluing. The spruce is reinforced with thin number 10 superglue.*
Photos 43 and 44. *The segmented saddle is thicknessed to the width of the saddle slot using my drum sander. The ends are then cut to fill the saddle slot with all the strings centered on top of the bone posts. The top of the segmented saddle is given a slant to the treble side, given by the measurements from the nut intonation, and the same radius as the fretboard. The segmented saddle is test fitted in the saddle slot and the depth of the slot is marked on the saddle with a pencil following the surface of the bridge. Using my measurements from the nut intonation and the depth of the slot, I can cut the height of the segmented saddle.*
Photo 45. *I glue a wooden shim on the underside of the segmented saddle to make it stronger. This also gives me another opportunity to adjust the height of the saddle if it turned out to be too low.*
Photos 46 and 47. *The saddle is fitted to the slot and adjusted for height, then filed to the correct intonation points.*









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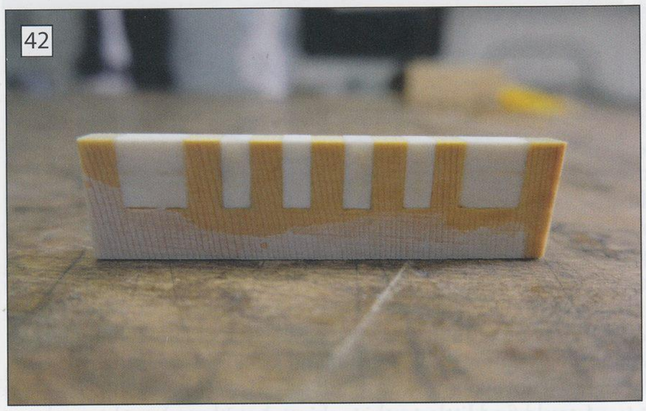

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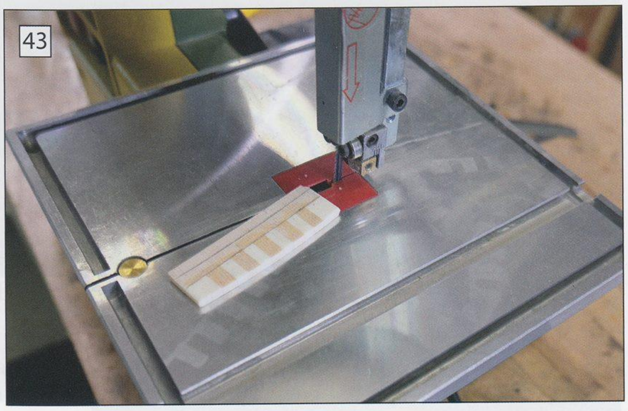

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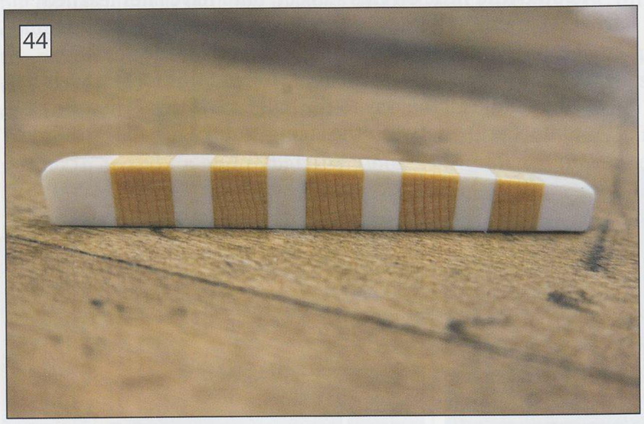

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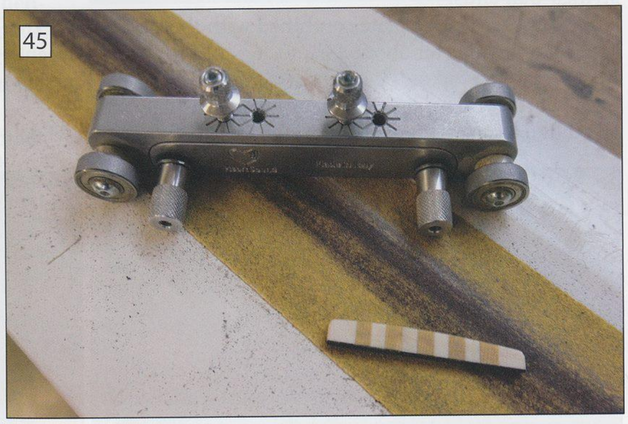

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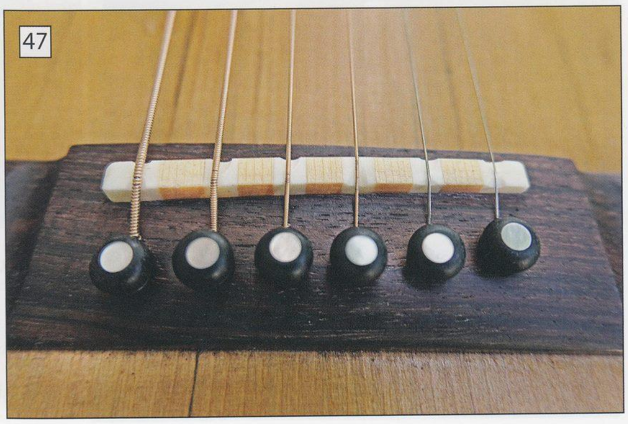

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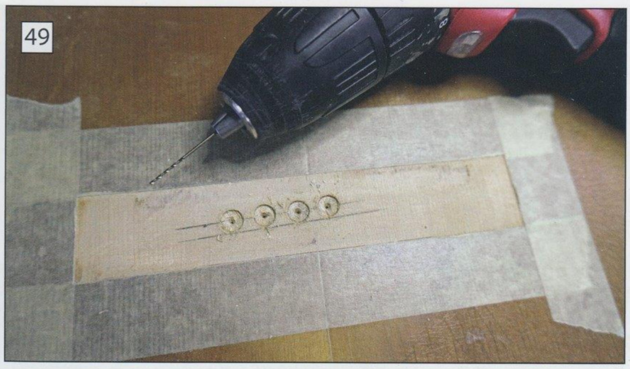
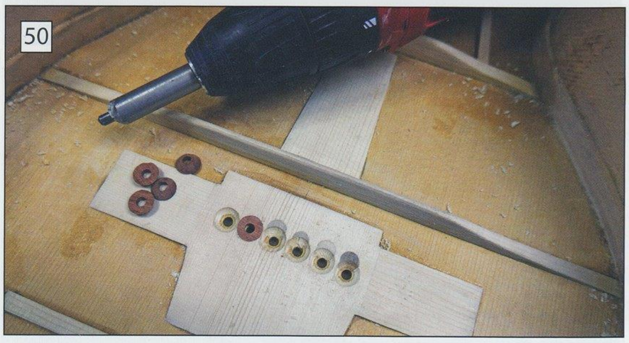
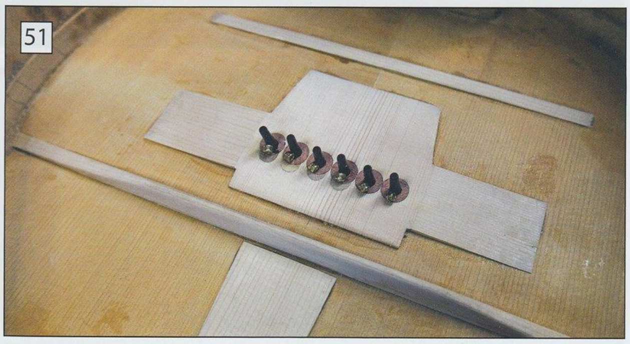


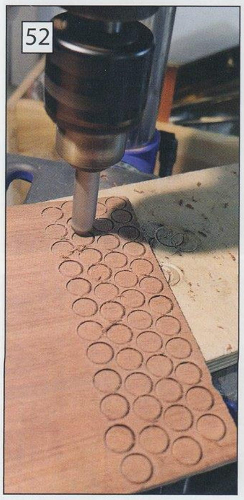


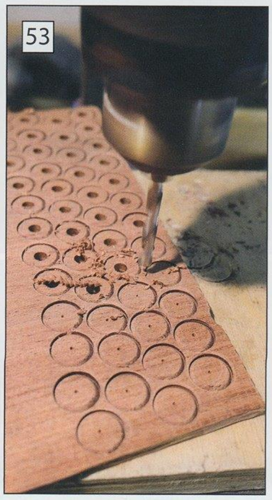


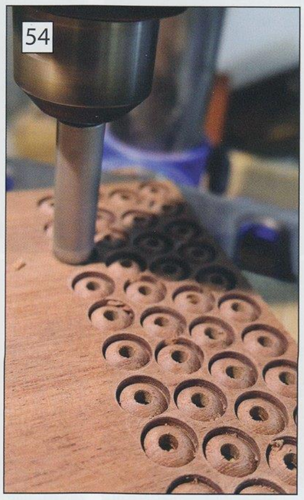
The segmented saddles have lower volume and less attack than solid-bone saddles, making the guitar sounding a bit too wimpy and kind. This was remedied by my next invention: hardwood plugs between the underside of the bridge and the strings' ball ends.

The spruce bridge plate combined with the thickness of the spruce top makes for about 4MM (0.16″) of soft wood between the ball end on top of the hardwood button and the underside of the hardwood bridge. My theory was that the soft wood acted like a spring that yielded to the tug of the ball end when a string is plucked, lowering its volume and attack. I remembered my previous experience with a brass PlateMate that gave an unpleasant metallic sound, and a chewed-up bridge plate that gave low volume and a dull sound.

I could find little on this subject, but I have later learned from Alan Carruth that the longitudinal tension force tugging on the ends of the string is about a seventh of the plucked transverse force. It is possible that some of this force travels over the saddle all the way to the ball end. If this is not the case, the contact point between the string and the top of the saddle







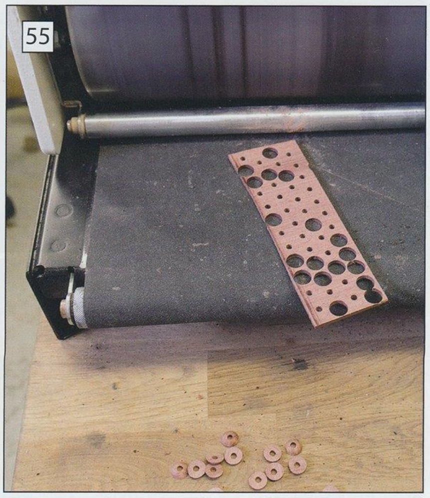


***Photo 48**. The bridge is in its location and the center of the string-pin holes are marked with the tip of a brad-point bit.*
***Photo 49**. Drilling 8MM holes in soft spruce for the plugs is tricky. I drill a small hole 4MM above the center of the string-pin holes as the center of the plug. Then I drill a couple of millimeters deep with an 8MM brad-point bit backwards from both sides using the small hole as the center of the brad point. Finally, I drill through the top and bridge plate with a sharp metal drill bit turning the right way. Doing it this way prevents most of the splintering of the spruce.*
***Photo 50**. Gluing the bubinga buttons using the StewMac BridgeSaver tool.*
***Photo 51**. All the ball ends rest on plugs and the hard buttons, except the two unwound strings with no plugs and only soft radial spruce to dampen volume and trebles.*
***Photos 52–55**. Making bubinga buttons using the StewMac BridgeSaver. Predrilled center holes make it easy to ream the string-pin holes. The buttons are sanded free using the drum sander from the back of the slightly too-thick bubinga plate.*

is the business end of the string. With a firmer anchoring of the ball end, the string may not slide as much over the top of the saddle, or the saddle won't micro-bend as much.

In addition to the plucked longitudinal tension force, there is also another tension force in the string. This force is a longitudinal compression wave called the clang or zip tone. It occurs when the string is plucked off center, and it has a high and often dissonant frequency. This tension force should be able to pass the saddle inside the core of the string and tug the ball end.

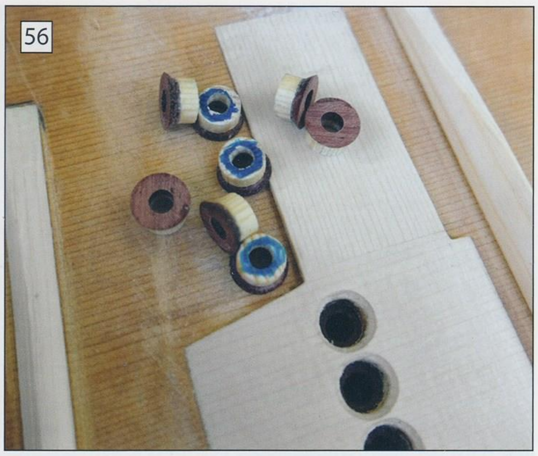
I drilled 8MM (0.31″) holes 4MM (0.16″) in front of the center of the bridge-pin holes, through the spruce bridge plate and the top (**Photos 48–51**). The holes were filled with hard birch dowels before gluing the bridge and mounting the hardwood buttons as described above. The ball ends thus rested against a firm support created by the hardwood button, the birch plug, and the bottom of the bridge. This gave a surprising increase in volume, attack, distortion, and treble response. The piercing, sharp sound of the two plain treble strings actually hurt my sensitive ears. I tried to find these characteristics appealing, but I realized that I had to find a way to tame the harsh tone.

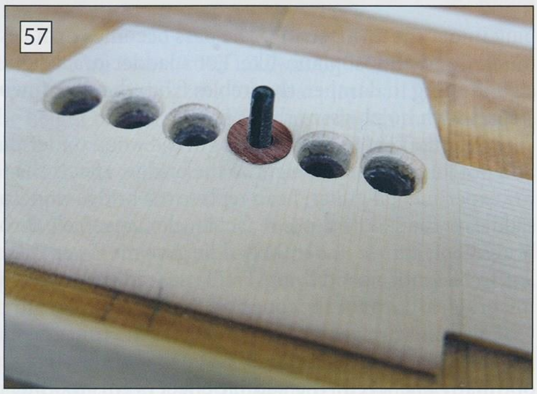
End-grain spruce is almost three times harder than spruce in any other direction, but still much softer than birch. I removed the birch plugs and replaced them with end-grain spruce plugs. This gave the same beautiful, complex tone as without plugs, but with higher volume, better attack, and increased clarity from the added trebles. The difference the plugs made was much greater than I would have imagined. By choosing the hardness of the plugs, we can thus regulate the combined volume, attack, treble, and distortion for each string. As far as I know, this is a new discovery.

I modified an old European-made parlor guitar as a test bed to pursue this idea. I made 9MM (0.35″) plugs in different woods and capped them with the same hard bubinga buttons as before. The middle hole is big enough for the ball end to pass through, and I use straight, thinned-down slotted bridge pins (instead of a reamed hole) to save time. I made the plugs fit tight enough in the holes to keep them in place without glue (**Photos 56–59**). I can easily loosen the strings and replace the plugs to different ones from inside the guitar.

Here is a chart of the Nordic woods I used and their Brinell hardness ratings in end-grain and radial directions. This information let me build a palette of different plug hardnesses.

	end grain	radial
spruce	3.2	1.2
alder	3.7	1.4
fir	4	1.9
birch	6.5	2.2–2.7
oak	6.4–6.6	3.4–4.1
red beech	7.2	2.7–4.0





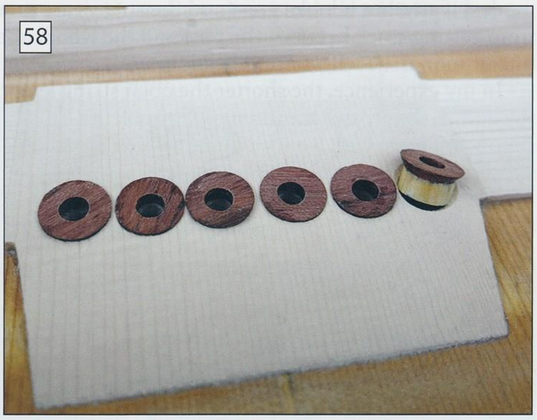


Photo 56. *The middle part of the spruce bridge plate in the test guitar has the same thickness around the 9MM holes centered at the bridge-pin holes for the loose plugs. I made many sets of plugs with different woods and grain directions, and marked them with different colors to tell them apart. The buttons are made of bubinga, but I also made a set of plugs with rosewood buttons. I could hear a small difference in tone; less trebles with the softer rosewood.*
Photo 57. *You can see the bottom of the rosewood bridge in the holes. The rim of the plugs will rest directly on the bridge. I sanded a set of slotted bridge pins straight and thin enough to fit the unreamed holes.*
Photo 58. *Loose plugs with a good enough fit to stay in place. The shank of a drill bit is used to loosen the plug through the string pin hole on the finished guitar. The color can be seen from above through the bridge pin hole.*
Photo 59. *Some of the plug sets with various woods and grain directions. Each type is marked with a different color and stored in a small jar.*

The best sound was when each string in a full chord had the same volume, and the midrange on the parlor guitar shone through. At first, I missed the dominating shimmer from the two unwound strings, but after a while the new tonal landscape was much more interesting.

Let S=Spruce, F=Fir, B=Birch, and R=Red beech; further, let upper case mean end grain and lower case mean radial grain. The setup with equal volume from the low E to high e strings that I preferred on the test guitar was BSFSss. I needed a little more volume and a harder plug for the D string, but this might not be the case for all parlor guitars. Thus, only four plugs are needed for this setup; the radial spruce for the two treble strings are already there in the form of the spruce top and bridge plate. Another well-balanced setup, with a bit more volume and overall roughness, is RFFFff.

The plugs restore the missing volume and attack that was lost with the segmented saddle compared with a solid bone saddle. The biggest improvement comes from the hard birch plug under the low E string. The bass becomes firm, less muddy, and almost piano-like. For a ladder-braced guitar, it's a good thing to dampen the trebles from the two unwound strings with no plugs, or softer plugs.

As for the bridge, the hardness of the wood under the saddle, and not just the sheer weight of the bridge, affects the tone. In my experimental guitar, I can replace the bridge wood under the saddle, as the saddle slot is in fact an elongated hole through the bridge. Soft spruce under the saddle gave me lower volume and less trebles, not a good thing. I still use traditional hardwoods in my bridges, both for the tone and for the durability.

I also add twelve metal bushings for the tuner posts in the slotted head. That way, the distal end of the string is optimally anchored. The audible effect of this modification is modest if any, but it looks great and the strings are prevented from getting stuck between the post and the wood, not an uncommon issue with slotted-head tuners.

In my experience, the shorter the open string length of the guitar, the greater the intonation problems. This can be a significant issue with a parlor guitar, which are small and have short scale lengths.

Even if a fretted guitar never can have perfect intonation, my aim is to get the best possible intonation with equal-tempered placements of straight frets. Adjusting for proper intonation at both ends of the strings means that we can approach perfect intonation at two different spots on the fretboard. I use the (standard) 12th fret as one of these, and I select the 3rd fret as the second; it's not too close to the nut, and it is often used in standard chords. I will adjust the contact points both at the bridge and at the nut until the open string, the fretted 12th-fret note, and the fretted 3rd-fret note are all in tune, then measure the location of those contact points.

Contrary to common misconception, no two guitars have exactly the same pattern of intonation points at the nut and saddle, although guitars with the same open string length and setup will have similar patterns. This means that no mathematical formulas can be relied on to achieve optimal intonation. Each guitar must be individually measured.

The bridge is a moving target. When a string is plucked, the bridge moves, and the string communicates with the behavior of the whole guitar. That affects the perceived pitch you and the tuner hear. More responsive guitars typically need more corrections at the nut and at the saddle.

The setup of the guitar must be spot on before you begin measuring for intonation. The string height at the 1st and 12th frets affects intonation at both ends. The neck relief should be minimal, almost flat. Fall off in the fretboard above the 12th fret will make the intonation worse in that area. The frets have to be well seated in the right positions and well crowned.

Wound strings can't be trusted. Even the same gauge from the same maker will have small variations in intonation. Sometimes a single string in a new set is way off. When I take my measurements, I always compare the result with a reference string to catch faulty wound strings.

To get the right pitch for the open-string note, the fretted 3rd-fret note, and the fretted 12th-fret note at the same time without retuning, both the nut and the saddle have to be adjustable when measuring. The positions for the adjustable nut and saddles need to be incrementally shifted forward and back, with a retune to pitch after every move, until all three reference notes have the correct pitch according to the stroboscope tuner. Moving one intonation point will necessarily affect the correct position of the intonation


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Photo 60. *To lengthen the fretboard before intonation measuring, I glue a piece of maple to the end. The height is leveled to the fretboard with a StewMac razor file. The tip of the file is covered with thin plastic tape to protect the fretboard.*

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point at the other end of the string. The nut mostly affects the open strings and the intonation of fretted notes for the lower frets. The position of the saddle affects the intonation of all the fretted notes, especially for the higher frets.

Before measuring, I remove the original nut and superglue a temporary extension to the end of the fretboard (**Photo 60**). I install a temporary zero fret and spreader nut to keep the strings in the right position across the fretboard. I use short, tangless zero frets with the same height as the rest of the frets as my adjustable "nut." To protect the fretboard when shuffling zero frets, and to emulate the real nut, which will be cut slightly higher than the frets, I place the zero frets atop a loose 0.05MM (0.002″) feeler gauge (**Photo 61**). A thicker feeler gauge is sometimes used if the string height at the 1st fret is too low, due to a fall-off of the fretboard above the 1st fret.

If possible, the same strings that the player will use should be used when measuring intonation. I use Newtone Heritage 0.012 low-tension strings as a standard on my restomods. They have about the same tension as a standard 0.011 set. The round core and low tension make the strings more flexible, so they will need a bit more room to vibrate and little higher action at the 12th fret compared to regular strings. The typical shorter string length of a parlor guitar also adds to lower tension and more flexible strings.

At the bridge, I use a special tool similar to the StewMac Intonator. It is a brass bridge pin with screws to adjust both the saddle height and the placement of the intonation point (**Photo 62**). With this arrangement, I can measure the intonation points for each string, one at the time, with all other strings tuned to tension (**Photo 63**).

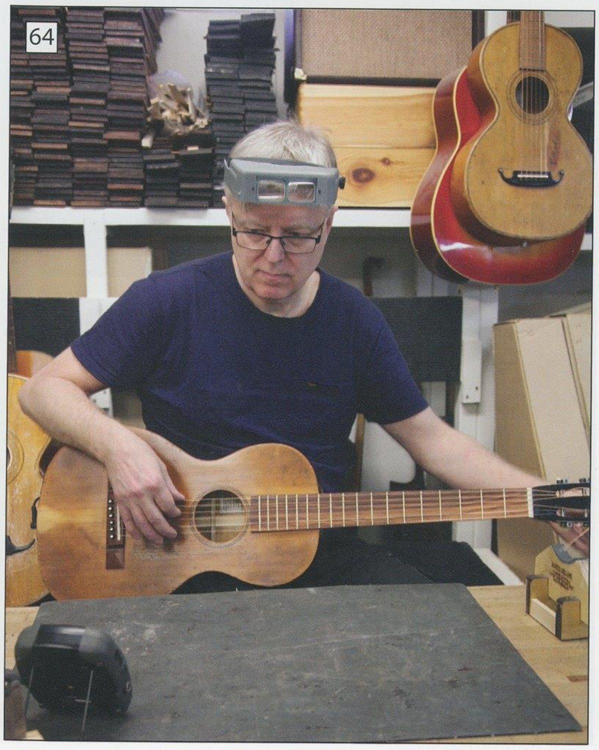
You need to give new strings a downward push close to the nut and saddle when first tuned to tension. If you don't, a new string will have a slight upward bow until it is fully stretched.

When I first began performing nut intonation, I used a tailpiece to anchor the strings. I soon learned to my surprise that a tailpiece gives different results than bridge pins. The wound strings need to be longer and the intonation slant of the saddle greater with bridge pins than with a tailpiece. Perhaps the sharper break angle over the saddle will pack together the windings on the bottom of the strings, making a short portion of the string so stiff that it doesn't participate in the strings' vibration.

String height at the 12th fret is one of the major factors that affects intonation at the saddle, so it's important to know how low the player likes to have the strings. My standard string heights above the 12th fret (bass to treble) are: 2.5MM (0.1″); 2.3MM (0.09″); 2.1MM (0.083″); 1.9MM (0.075″); 1.7MM (0.067″); 1.5MM (0.06″). This works without buzzing for most players.

The height of the "saddle" is adjusted with the special tool until the desired string height at the 12th fret has been set. The zero fret at the nut automatically gives the correct string height at the 1st fret.

When reading the tuner, it's important to hold the guitar in the playing position (**Photo 64**). Gravity will change the shape of the guitar. Also, it's important to fret the string with a similar light touch every time. If the customer is heavy-handed, the measuring should be done with the same heavy hand for best results for that player. It can be easier to get a good reading with the tuner if a pickup is used. Most of the time I include a K&K pickup in my restomods, but if not, I tape the transducers of a loose K&K pickup to the top below the bridge.



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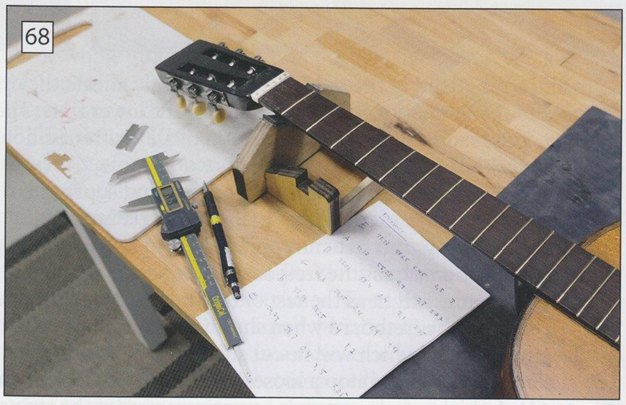
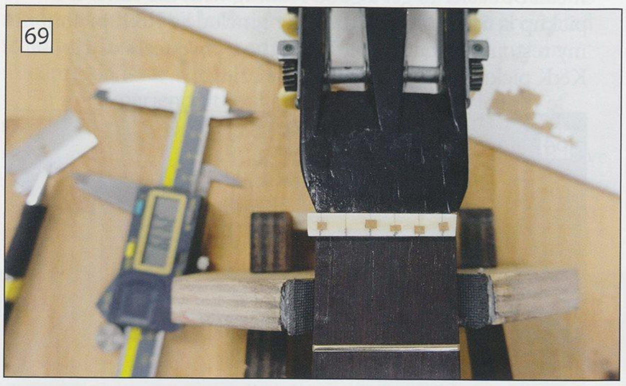
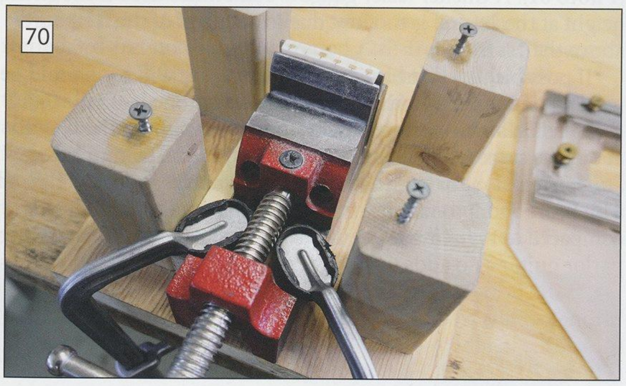
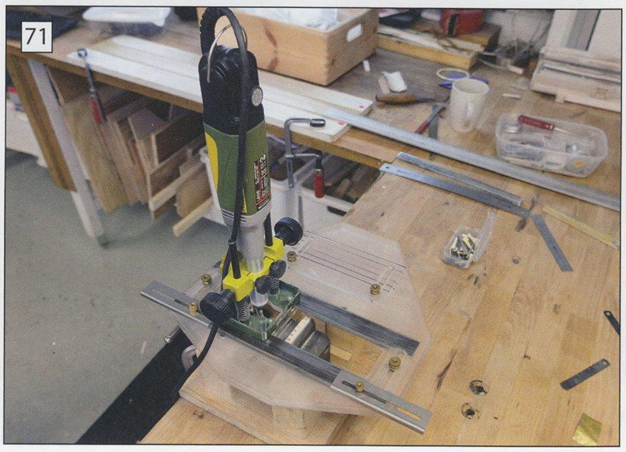
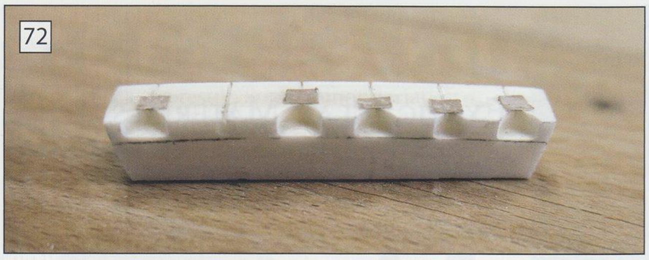


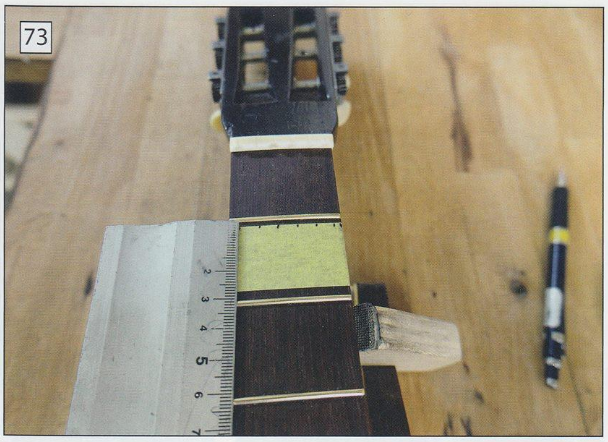






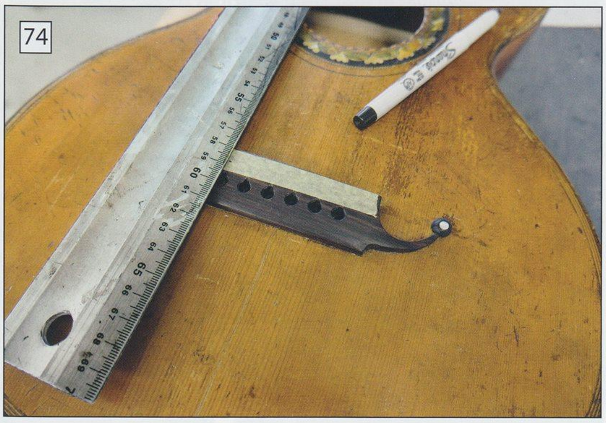
Photos 65 and 66. *The adjustable zero frets at the nut are in place and the special intonation tool is installed on the bass E string at the bridge with all strings tuned to tension. All the tools I need, including feeler gauges, a "shuffler" for the nut zero frets, and the stroboscope tuner, are ready. The nut and saddle intonation for each string is measured.*
Photo 67. *Cutting the end of the fretboard at the nut intonation point that came closest to the 1st fret.*
Photos 68 and 69. *The measurements are noted on a piece of paper for each string. Small pieces of dark tape are put on the top of the nut, using the measurements, to mark the intonation points. The dark tape makes is easy to see exactly how far into the nut I have to mill.*
Photos 70 and 71. *I use a simple jig to mill the intonation cuts of the nut. This jig is an adaptation of my reinforced StewMac bridge slotting jig. I also use the small StewMac vise.*
Photo 72. *I mill to the very edge of the tape marker with a 4MM diamond abrasive bit. The depth of each cut is milled down to the surface of the fretboard as marked on the nut with a sharp pencil.*
Photos 73 and 74. *With a long ruler I mark all the measured saddle intonation points on top of the bridge from the origin behind the 1st fret.*

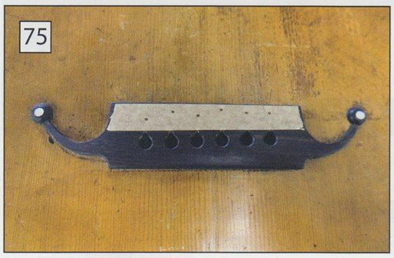


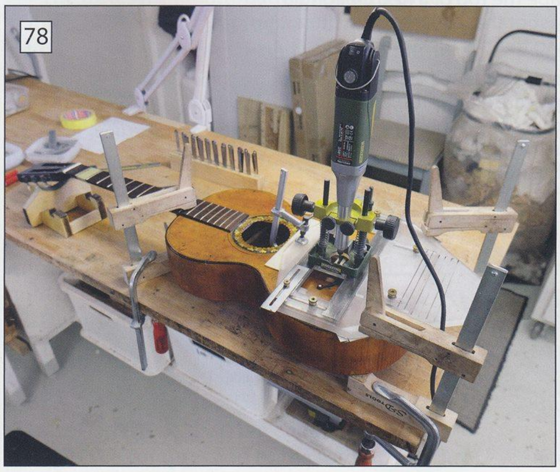


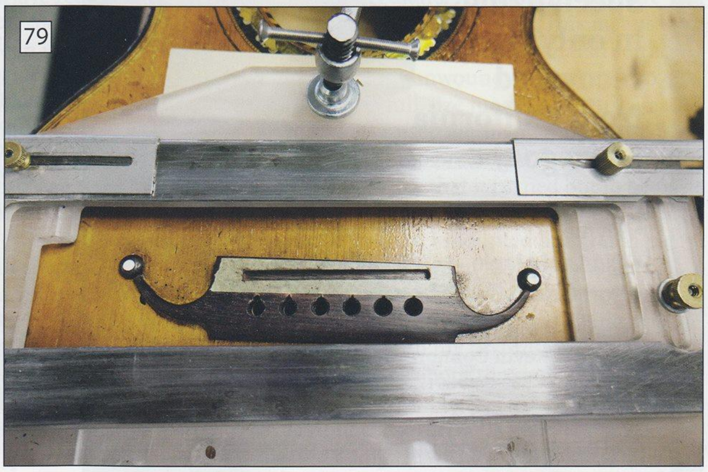
I begin measuring with the zero fret at the top of the fretboard and move the intonation point at the saddle to the position given by a standard 12th-fret intonation. Then I tune to the fretted 3rd-fret note. If the open string is too low in pitch, I move the zero fret closer to the 1st fret and retune to the fretted 3rd-fret note. If both the open string and the fretted 3rd-fret note are in pitch, I check the fretted 12th-fret note and adjust the saddle accordingly… and so on. After spending the requisite amount of time shuffling the zero fret up and down, and adjusting the screw at the saddle end forward and back, and retuning the string after each adjustment, the string will attain correct pitch at all three reference points at the same time without retuning.

To record these positions, I use the back side of the 1st fret under the string as the origin, and measure the distance from the origin to the center of the zero fret at the nut with a digital caliper. Then I measure the distance from the same origin to the intonation point at the saddle with a long ruler. I write down the name of the string, the distances to the nut and saddle intonation points, the string height at the 1st and 12th frets, and the height of the saddle on a piece of paper. I use these measurements to cut and adjust the intonated nut, and to place, cut, and adjust the saddle in the bridge.









Photos 75, 76, and 77. *I use thin plastic tape on top of the bridge for marking the intonation points. I draw the slanted rectangle needed for the saddle slot that contains all the intonation points, typically 4mm–4.5mm wide.*

The rectangle is cut out with a razor blade to make it easy to see exactly where to mill the slot. ***Photos 78 and 79.*** *Milling the saddle slot using the StewMac jig and my high-quality Proxxon "Dremel" tool.*

As a last precaution, not to be fooled by a new faulty wound string, I replace the measured wound string with a similar reference string and double-check the result. Some minor variation is to be expected. The loose zero fret needs to be restored to the measured spot again, but because the special tool is already adjusted to the correct spot with the adjustable screws, double-checking is not that time-consuming. I don't double-check the unwound strings.

I repeat this for all six strings. The whole process typically takes about four hours. I might add that this is a really boring job to do, but the end result makes it worthwhile.

When the measuring is done, the end of the fretboard can be cut to the intonation point closest to the 1st fret, which is usually the A or B string on a parlor guitar. This allows for a rectangular nut, which is not as conspicuous as a nut with an irregular shelved front edge, in my opinion. The string slots in the nut are milled back with a Proxxon "Dremel" tool with a straight 4MM (0.16″) diamond grinder bit to the measured intonation points for the other five strings.

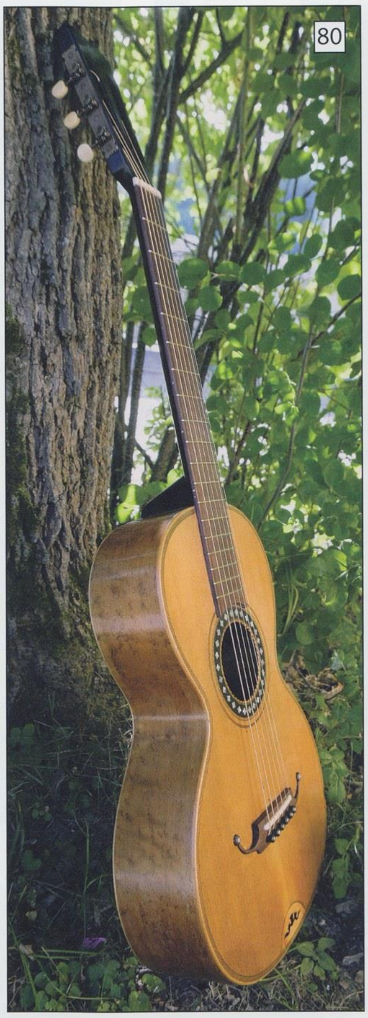
The intonation points are marked on top of the bridge and a slanted saddle slot is milled wide enough to accommodate all the points. The segmented saddle is shaped and cut to the intonation point on top of the bone posts. (*See* **Photo 47** *on p. 15*.) I use the measured saddle intonation positions as a reliable starting point and use the standard 12th-fret intonation method to fine tune the final saddle intonation.

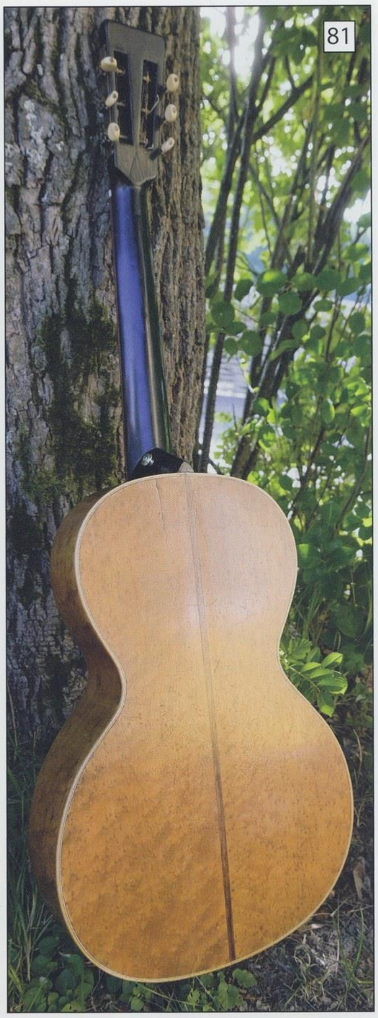
With a successful nut and saddle intonation, all the standard chords near the nut will feel relaxed and in tune. Tone will improve and sustain will increase, most likely due to better matching overtones in all strings. Intonation will be better when a capo is used because the intonation of the saddle is only done for the fretted notes, and not compensating for errors resulting from a straight misplaced nut now disconnected by the capo.

The finished nut intonation remains pretty stable, even when changing to a different string set or string thickness, given the same tuning and string height at the 1st and 12th fret as when measured.

I am a simple chord player myself, and the better tone, increased separation between the strings, and better intonation near the nut make a guitar come alive for me. If I play sloppily, the enhanced tonal clarity and string balance imparted by the plugs provides less cover in tonal mud or excessive trebles than before.

Unfortunately, the segmented saddle and plugs don't work well with nylon strings. The initial attack tends to be defeated by the rubbery properties of the strings, and not as much force is transmitted to the string ends as with steel strings. The compression of the sound, and the trebles and high volume of a solid bone saddle, is a good thing on a nylon-strung guitar. Besides, very few nylon-strung guitars have a pin bridge.





Photos 80 and 81. *The finished test guitar. I gave it a new fingerboard, a replica bridge, and a mounted K&K pickup. It is strung with and intonated for Newtone Heritage 0.012 strings. This guitar sports rare solid bird's-eye maple in the sides and back.*

I have recently restored three X-braced guitars. X bracing gives more bass response, and sometimes it is the treble that is lacking. This means that you can use harder plugs on the treble side without getting a harsh sound. I used BSFSSS plugs (end-grain spruce for the unwound strings) on two of them with good results. One was actually a full-size modern Scottish-made Moon-brand dreadnought from the 1990s. I used all the methods I use for my normal parlor restomods, including new top bracing and a carbon rod instead of a broken truss rod. I can honestly say that it turned out to be one of the best X-braced guitars I have played. The third one was the muddiest and darkest-sounding guitar I have ever played. I mounted hard birch plugs for all strings, BBBBBB. The sound became better but still a bit muddy. The extra volume and treble coming from the plugs do have a limit.

So, how much better is the old guitar with the modifications I've described? Compared to the original, a lot. Compared with my first restomods without all the novel adjustments I make now, perhaps about the same degree of improvement as putting on a new set of strings.

But don't take my word for it. Try out these methods yourself. Try cedar and spruce in a segmented saddle and compare with a solid-bone saddle. Try with and without plugs and/or a spruce bridge plate. Do your first nut intonation. The best results will surely come with all the methods combined. And if you do, let me know how it all turned out! —